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DEVELOPMENT OF COST-OPTIMIZED INSULATION SYSTEM FOR USE IN LARGE SOLID ROCKET MOTORS

Volume II: Task II - Process Evaluation

by:

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and

D. L. Nachbar, Project Manager, LMISD Program

AEROJET-GENERAL CORPORATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA Lewis Research Center
Contract NAS3-11224
J. J. Pelouch, Jr., Project Manager

AEROJET GENERAL TIRE GENERAL

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FINAL REPORT

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FOREWORD

The insulation development work described herein, which was conducted by the Solid Rocket Division of Aerojet-General Corporation, was performed under NASA Contract NAS3-11224. The work was accomplished under the management of the NASA Project Manager, Mr. J. J. Pelouch, Jr., Chemical Propulsion Division, NASA-Lewis Research Center.

Special acknowledgements for work accomplished in Task II are accorded to Messrs. P. L. Smith and J. A. Conyers for planning and conduct of the insulation material process evaluation demonstrations, and to Messrs. R. H. Henderson and W. T. Jacobs of The DeVilbiss Company, San Jose, California, for their cooperation and assistance in development of spray techniques for IBS-107 and IBS-109 insulation materials.

TABLE OF CONTENTS

FIGURE LIST

FIGURE LIST (cont)

ABSTRACT

A program to develop a cost-optimized insulation system for large solid rocket motors was conducted by Aerojet-General Corp. under Contract NAS3-11224. Four tasks were derived to accomplish the program objective: Task I, Survey and Screening; Task II, Process Demonstration; Task III, Material Performance Determination; and Task IV, Preparation of 260-in.-dia full-length motor insulation system Design and Process Plan. Task II is the subject of this volume of the final report. This included process evaluation demonstrations. Process evaluations with IBT-106 showed this material and process to be a prime consideration for large motor sidewall insulation and propellant boot applications. Troweled IBT-100 and TI-H704B and cast IBC-111 and 40SD-80 provided adequate dome insulation. Demonstrations of the sprayable materials, IBS-107 and IBS-109, as sidewall insulation indicated that more development work is necessary before spray application can be adapted for use in large motors.

NASA report numbers and corresponding volume numbers are as follows;

CR-72581	Volume I
CR-72582	Volume II
CR-72583	Volume III
CR-72584	Volume IV

I. SUMMARY

The objective of the Large Motor Insulation System Development (LMISD) Program is to evaluate low-cost insulation materials which are applicable to large solid-propellant rocket motors. Four tasks were derived to accomplish the planned objective. Task I, which is described in Volume I of this report, involved a survey of available materials applicable to large motors; selection of twenty candidate materials, including Gen-Gard V-44 and V-61 as controls; measurement of candidate material physical, chemical, mechanical, thermal, and adhesive properties; evaluation of material erosion resistance in three solid-propellant motor tests; evaluation of property measurement and motor test data; and selection of twelve materials, including V-44 control, for further evaluation in Tasks II and III. In Task II, which is the subject of this volume, candidate materials selected in Task I were installed into a 54-in.-dia motor chamber. Task III includes material performance determinations in five solid-propellant motor tests. Task IV is the preparation of a 260-in.-dia full length motor cost-optimized insulation system design and process plan, using materials selected on the basis of data obtained from Tasks II and III.

The following materials were recommended for process evaluation in Task II:

Trowelable	Castable	Sprayable
IBT-100	IBC-101	IBS-107
IBT-106	IBC-111	IBS-109
TI-H704B	40SD-80	Avcoat II

100 to 300 lb of each material were installed into various sections of a 54-in.-dia demonstration test chamber, using installation techniques which were applicable to large motors and to the specific material being evaluated. A Polaris A-2P, first-stage, steel case, SN 1PA2-58, was rehabilitated, cleaned, and primed with Fuller 162-Y-22 for use as the 54-in.-dia test chamber. Insulation materials were mixed in a 30-gal Baker-Perkins vertical batch mixer. After mixing, a pressure diaphragm was installed, and material was extruded out of the mix-bowl bottom draw off for troweling and casting demonstrations. A Cowles Dissolver was used to mix the smaller batches of IBS-107 and IBS-109 required for the spray demonstrations.

Ten insulation material process evaluation demonstrations were conducted as described briefly in the following paragraphs.

A. IBT-106 was evaluated as a trowelable sidewall insulator. Material was fed into a 12-in.-wide, modified liner trowel, and extruded through a slot at the back of the trowel while the chamber was manually rotated on turning rolls. The trowel exit slot was sized to obtain a 0.25-in.-thick ply of IBT-106. After 48 hr cure at 135°F, the IBT-106 sheets were stripped and inspected. Material thickness ranged from 0.25-in. at the center of each 12-in.-wide strip to 0.17-in. at the joint between adjacent strips. The thickness reduction

I. Summary (cont)

apparently was caused by removal of a 1.0-in.-high ridge of material formed during installation. There were no significant surface discontinuities, and sectioned specimens showed the material was void free. To improve this method of sidewall insulation application, constant-speed motor driven turning rolls, a weighted, mobile trowel, and spiral strip patterns were required.

B. IBT-100 was evaluated as a trowelable dome insulator. Material was extruded into the chamber dome, and a sweep template/trowel, mounted and centered in the igniter boss, was used to distribute approximately 180 lb of IBT-100 to the desired configuration. The thickest section was 4.0-in., tapered to 0.5-in. at the sidewall. Overlapping and side-by-side passes were used to extrude IBT-100 into the dome; post-cure inspection revealed the overlapping technique produced a defect-free specimen.

C. IBC-111 and 40SD-80 were evaluated as castable dome insulators in a fiberglass mold fabricated using the IBT-100 segment as a mandrel. Approximately 150 lb each of IBC-111 and 40SD-80 were bottom-cast from the mix bowl through 1.0-in.-dia tubing. Post-cure radiographic inspection and inspection of cut specimens showed that the cast materials were void- and defect-free. Mechanical property tests conducted on 40SD-80 specimens taken from the cured segment showed significant "hardening" between small and large batch processing of this material, apparently caused by the high exothermic cure reaction. Although the short pot life of 40SD-80 is undesirable, the "hardening" effect does not prohibit the use of castable 40SD-80 in large motor applications.

D. IBT-106 was demonstrated as a trowelable propellant boot. A sweep template/trowel, with a 0.25-in. constant stand-off distance from the released dome surface was mounted and centered in the igniter boss. IBT-106 was extruded from the mix bowl in front of the template and troweled into a 0.25-in.-thick simulated propellant boot. Post-cure inspection revealed only several minor underside surface defects, apparently caused by material adhering to the trowel and pulling away from the released surface. Two process changes were derived from this demonstration. First, the trowel configuration should be modified to reduce the area of the trowel in contact with IBT-106. Second, the amount of material extruded in the dome in front of the trowel should be as small as possible to minimize the force required to move the trowel.

E. A combined demonstration of IBT-100 as a trowelable dome insulator and IBT-106 as a trowelable propellant boot was conducted to simulate as nearly as possible the sequence of processing operations that would be encountered in an actual motor. IBT-100 was troweled into the dome as previously described and overlapping passes were used to obtain a defect-free demonstration. After 48 hr cure at 135°F, DC-Q-92 Silicone release was applied to the insulation surface. IBT-106 was troweled over the released insulation surface to form a

I.E. (Cont)

0.25-in.-thick propellant boot. When the cured IBT-106 boot was pulled away from the released IBT-100 insulation surface, no surface defects were observed. The success of this combined process evaluation was a significant step in demonstrating the feasibility of using low-cost, trowelable materials in large motors.

F. IBS-107 and IBS-109 were demonstrated as sprayable sidewall insulators. Process development work required for spray application of these materials were accomplished by the DeVilbiss Company, San Jose, California. Approximately eight trial panels, with varying amounts of solvent reduction and fluid temperatures, were completed by DeVilbiss engineers before acceptable results were obtained. DeVilbiss engineers, using their equipment, sprayed a 0.25-in.-thick section of sidewall insulation with IBS-109 in the 54-in.-dia case. Approximately 30 min after application, the material near the vertical began to sag, and eventually slumped into the bottom of the case. IBS-107 was applied to the sidewall to a thickness of 0.05-in. and then rotated to the overhead and vertical positions. No slump or sag was observed. However, some of the material dripped to the bottom of the case.

Three conclusions were gathered from these demonstrations. First, multiple applications of sprayable material are required, with at least a 24-hr ambient gel time between applications. 0.05 to 0.07-in.-thicknesses can be sprayed at each application. Second, continual chamber rotation during gel and cure is required to prevent material running or dripping. Third, the solvent used to reduce material viscosity is flushed-off during the spray operation, so that the material applied to the sidewall is free of residual solvents.

G. TI-H704B was demonstrated as a trowelable dome insulator. The sweep template/trowel used for instllation of IBT-100 also was used for this process evaluation. Difficulty with this troweling process indicated that a pneumatic tamping process for TI-H704B installation is required.

H. IBT-106 was demonstrated as a sidewall insulator. This was a repeat of the first sidewall process evaluation, except that the material was applied in continuous spiral passes through a slightly modified trowel configuration designed to minimize the size of the ridge formed between adjacent strips. One circumferential and three spiral strips were applied. The cured IBT-106 was free of defects; thickness varied from 0.20 to 0.25-in. This method of sidewall insulation application appears very attractive for large motors.

II. INTRODUCTION

A. PURPOSE OF REPORT

This document is the second volume in a series of final reports dealing with the major tasks of the Large Motor Insulation System Development (LMISD) Program, Contract NAS3-11224. This series of reports constitutes the LMISD Program final report. This report summarizes the Task II effort for the LMISD Program.

B. SCOPE OF EFFORT

This report volume summarizes the Task II effort for the LMISD Program. The following work was accomplished:

1. Preparation of the 54-in.-dia Polaris A2P, first-stage chamber.
2. Demonstration of IBT-106 as a trowelable sidewall insulator.
3. Demonstration of IBT-100 as a trowelable forward/aft dome insulator.
4. Demonstration of IBC-111 as a castable forward/aft dome insulator.
5. Demonstration of 40SD-80 as a castable forward/aft dome insulator.
6. Demonstration of IBT-106 as trowelable propellant boot material.
7. Composite demonstration of IBT-100 as a forward/aft dome insulator, with IBT-106 overlayed as a trowelable propellant boot.
8. Demonstration of IBS-109 as a sprayable sidewall insulator.
9. Demonstration of IBS-107 as a sprayable sidewall insulator.
10. Demonstration of TI-H704B as a trowelable forward/aft dome insulator.
11. Demonstration of IBT-106 as a trowelable sidewall insulator.

III. ASSOCIATED OPERATIONS

A. TEST CHAMBER PREPARATION

Task II insulation material process evaluation demonstrations were conducted in a 54-in.-dia, 120-in.-long Polaris A2P, first-stage steel chamber. The chamber originally was processed and test fired as Polaris Motor SN 1PA2-58. Residual liner and epoxy bonded V-44 rubber were removed from the chamber prior to initiating the process evaluation operations.

The chamber was moved into Aerojet's 55-in.-dia autoclave and heated to approximately 400°F to break-down the liner and epoxy bond prior to removal of residual liner and insulation. The interior surface then was vacuum-blasted with 80-grit sand. Following removal of sand and solvent cleaning, the chamber interior was primed with Fuller 162-Y-22. This was the primer previously used for the 260-SL motor chambers.

B. INSULATION MATERIAL PROCESSING

Insulation materials were dispensed in two parts; those ingredients which react to form the polymer were placed in two separate parts, and the solid filler materials were divided between the two parts. The Cowles dissolver was used to blend each part into a homogeneous mixture. The two mixtures then were added to the 30 gal Baker-Perkins vertical batch propellant mixer and mixed under vacuum at 80°F for 30 minutes. Draw off was facilitated by pressure casting from the mix bowl, with the use of a diaphragm and air pressure.

IV. PROCESS EVALUATION

Evaluation of processing techniques was conducted for the ten materials recommended as a result of the Task I material evaluation effort reported in Volume I of this final report. The following materials were recommended and approved for Task II process evaluation:

<u>Pressure Cured Group</u>

V-44 Control, NBR/silica/asbestos

USR-3800, NBR-phenolic/boric acid

<u>Trowelable Group</u>

IBT-100, PBAN-epoxy/Sb_2O_3/Asbestos

IBT-106, PBAN-epoxy/Sb_2O_3/Asbestos

TI-H704B, PBAA/Carbon black/Asbestos

IV. Process Evaluation (cont)

Castable Group

IBC-101, PBAN-epoxy/Sb_2O_3/Asbestos

IBC-111, PBAN-epoxy/Refrasil

40SD-80, Polyurethane

Sprayable Group

IBS-107, CTPB/Sb_2O_3/Silica

IBS-109, PBAN-epoxy/Sb_2O_3/Asbestos

Avcoat II, Epoxy-polyamide

Ten process evaluation demonstrations were performed. No process demonstrations were required for the pressure cured or IBC-101 castable materials. The planned effort was as follows:

Dome Sections (6 materials with 5 demonstrations)

1 calendered material (V-44 w/V-61 seams, no demonstration)

2 trowelable materials

2 castable materials

1 sprayable material

Cylindrical Section (4 materials with 3 demonstrations)

1 calendered material (V-44 w/V-61 seams, no demonstration)

2 trowelable materials

1 sprayable material

Boot Section (3 materials with 2 demonstrations)

1 calendered material (V-45 w/Germax seams, no demonstration)

1 trowelable material

1 sprayable material

Approximately 100 to 300 lb of each mastic material were installed in either constant thicknesses to simulate cylindrical section and boot section evaluation or tapered thickness to simulate dome section evaluation. The following installation techniques were demonstrated:

Troweling into place (applicable to dome, cylindrical, and boot sections)

Ambient casting into molds and secondarily bonding into place (applicable to dome sections only)

IV. Process Evaluation (cont)

Casting into place using a half-mold (applicable to dome sections only)

Spraying into place (applicable to cylindrical and boot sections)

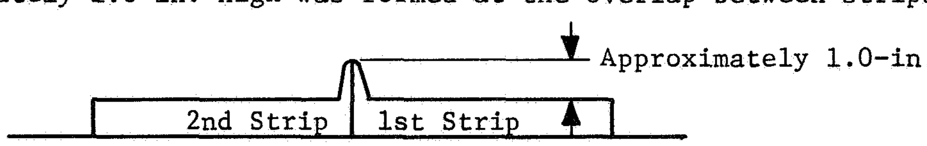
For a particular material, only those techniques that lent themselves to the properties of the material were demonstrated. Uncured troweled, cast in-place, and sprayed installations were rotated to vertical and inverted positions to evaluate the slump and shear properties of the uncured installation in a situation analogous to large motor processing conditions. The evaluation included slump characteristics, quality, ease of repair, special tools, critical process parameters, process aid costs, and labor hours. The following sections describe in detail the individual process evaluation demonstrations.

A. IBT-106 SIDEWALL INSULATION DEMONSTRATION

IBT-106 PBAN-epoxy was demonstrated as a trowelable, sidewall insulation material. The material was mixed in a 30-gal Baker-Perkins vertical batch mixer as described previously in Section III.B of this report volume. Mixed IBT-106 was forced from the mixing bowl through the bottom draw-off using a pressure diaphragm and fed into the annulus of a trowel. The overall demonstration set-up is shown in Figure 1. The trowel configuration is shown in Figure 2. The trowel used for IBT-106 sidewall installation was designed originally for application of SD850-2 liner material in 260-SL motors.

The interior surface of the 54-in.-dia chamber which was to be insulated was released with DC-Q-92, except for a 12-in.-sq section. The purpose of the release was to facilitate removal of the cured material for inspection and property evaluation. Two 0.25-in.-thick by 12-in.-wide strips of IBT-106 were applied to the chamber sidewall, as shown in Figure 3.

When all connections were complete, the mix bowl was pressurized to 60 psig. As material began to fill the trowel annulus (Figure 3), the chamber was manually rotated, while an operator inside the chamber controlled the trowel. After the first strip was applied, mix bowl pressure was relieved, and excess material was removed from the trowel. The trowel was moved to the next strip position, and the foregoing procedure was repeated. The trowel and actual demonstration are shown in Figure 4. A 1.0-in. overlap between the first and second strips was allowed. As shown in the following sketch, a ridge approximately 1.0-in. high was formed at the overlap between strips:



This ridge was removed by using a spatula wet with trichlorethylene solvent. The completed sidewall insulation was wiped with solvent to obtain a clean, smooth surface.

IV.A. IBT-106 Sidewall Insulation Demonstration (cont)

The completed demonstration unit was allowed to stand for 48 hr at ambient temperature. During this period there was no evidence of slump or sag. The chamber was not rotated at any time, so that material at 90, 180, and 270 degrees remained in that position for the entire 48 hr ambient cure cycle. The ends of the chamber then were enclosed with plywood covers, and 135°F air was circulated through the chamber interior for 48 hr. After cure, the IBT-106 was stripped from the chamber as shown in Figure 4, except for the unreleased 12-in.-sq section.

The cured IBT-106 was sectioned every 12-in. around the circumference, and each section then was cut longitudinally along the joint between strips. Thickness measurements ranged from the desired 0.25 to 0.17-in. The 0.17-in. thickness occurred at the joint between strips, and this thickness reduction apparently was caused when the ridge was removed with spatulas. All sections were free of defects, except for isolated instances of minute voids observed along the joint between strips. Since these minute voids were located only along the joint, it was concluded that they were caused by the ridge removal operation. The mechanical properties of IBT-106 specimens taken from the process demonstration are shown in Figure 5. Included in Figure 5 for comparison are the mechanical property values quoted by the material supplier and the values obtained from Task I property tests.

Three improvements were apparent for this installation process. First, constant-speed, motor driven turning rolls such as those used for the 260-SL motor are essential to control thr trowel speed in relation to the material flow rate to the trowel. For the IBT-106 demonstration, the chamber was rotated manually, making it necessary for the operator inside the chamber to adjust the speed of the trowel, while at the same time maintaining his balance and maintaining pressure on the trowel. Second, a weighted trowel is necessary to prevent "floating". When rotation speed and material flow are adjusted properly, the tendency for the trowel to "float" is reduced significantly. The addition of weights will insure that the trowel rides on the chamber wall at all times. Third, a spiral strip pattern eliminates the necessity of stopping the chamber, moving the trowel to the adjacent position, and continuing the next strip.

With these improvements, this method of troweling IBT-106 as motor chamber sidewall insulation appeared very attractive. The elapsed time required to apply two, 12-in.-wide strips to the chamber sidewall (4070-in.^{2}) was 10 min; this time included moving the trowel after the first strip was installed. Projecting this time lapse to the 1066-in.-long (tangent-to-tangent) 260-FL motor sidewall ($\sim$870,000-in.^{2}), the following conservative installation span times were estimated:

IV.A. IBT-106 Sidewall Insulation Demonstration (cont)

	Hr	Shifts
Setup Time	8	1
Application Time	36	4.5
Cure at Ambient	24	3
at 135°F	48	6
Clean-up Time	8	1
Total Estimated Span Time	124	15.5

Approximately 4000 to 4300 lb of IBT-106 can be mixed in one bowl at the Vertical Mix Stations, resulting in a requirement for approximately 1.5 to 2 batches for the 260-FL motor sidewall.

B. IBT-100 DOME INSULATION DEMONSTRATION

IBT-100 was demonstrated as a trowelable, forward and aft head insulator. The material was mixed in a 30-gal Baker-Perkins vertical batch mixer as previously described. Mixed IBT-100 was forced from the mixing bowl through the bottom draw-off using a pressure diaphragm, and fed through a nozzle into the head of the motor; the overall demonstration set-up is shown in Figure 6.

The interior surface of the 54-in.-dia chamber forward head which was insulated was released with DC-Q-92, except for a 12-in.-sq section. The purpose of the release was to facilitate removal of the cured material for inspection and property evaluation.

As shown in Figure 7, approximately one-third of the dome section was insulated. The thickest section was 4.0-in., tapered to 0.5-in. at the sidewall. The contour was controlled by a manual template/trowel mounted in the forward boss of the dome. A pneumatic vibrator was mounted on the trowel to minimize material accumulation on the trowel during the operation. The material was applied to the chamber through a 2-in.-dia nozzle; the mix bowl was pressurized to 60 psig. As shown in Figure 8, two methods of distributing the material were tried. The first method was a side-by-side pass (Figure 8A); the second was an overlapping pass (Figure 8B). The elapsed time required to install 180 lb in the chamber dome was 60 min. Projected to a full-length motor, the estimated span times required to insulate the domes based on this demonstration is as follows:

IV.B. IBT-100 Dome Insulation Demonstration (cont)

	Hr	Shifts
Setup Time	8	1
Apply/Trowel Insulation	24	3
Cure at Ambient	24	3
at 135°F	48	6
Clean-up Time	8	1
Total Estimated Span Time	108	14

When the desired configuration was achieved, the surface was washed with trichlorethylene solvent to obtain a clean, smooth surface. The completed demonstration was cured in a 135°F oven for 48 hr.

After cure, the periphery of the segment was trimmed to obtain clean, distinct edges. Release material was applied and fiberglass was layed-up over the IBT-100 segment to form the mold for subsequent casting demonstrations. The cured fiberglass mold was stripped from the segment, then the segment was removed from the chamber.

Inspection of the backside surface and radiographic inspection of the IBT-100 segment revealed defects associated with the side-by-side method of distributing material. The defect and the origin of the defect are depicted schematically in Figure 8A. As each bead of material was applied, a void space was formed, and material dispersion with the trowel failed to eliminate this defect. In the area of the IBT-100 segment where material was applied by overlapping passes (Figure 8B), no defects were observed.

The mechanical properties of IBT-100 specimens taken from the demonstration are included in Figure 5.

C. IBC-111 DOME INSULATION DEMONSTRATION

IBC-111 was demonstrated as a castable, forward and aft head insulator. The material was mixed in a 30-gal Baker-Perkins vertical batch mixer, forced from the mixing bowl through the bottom draw-off using a pressure diaphragm, and bottom-cast into a fiberglass mold installed in the head of the motor. The overall demonstration set-up is shown in Figure 9.

The interior surface of the 54-in.-dia chamber forward head which was to be insulated was released with RTV silicone rubber, except for a 12-in. sq section.

IV.C. IBC-111 Dome Insulation Demonstration (cont)

As shown in Figure 10, approximately one-third of the dome section was insulated. The thickest section was 4.0-in., tapered to 0.5-in. at the sidewall. The contour was controlled by the fiberglass mold, which was sealed in position with RTV-732 sealant.

One hundred twenty pounds of IBC-111 was bottom-cast into the mold through 1-in.-dia plastic tubing. Initial pressure in the mix bowl was maintained at 20 psig until the integrity of all connections was verified; then pressure was gradually increased to 30 psig during the demonstration. The elapsed time required to fill the mold was 30 min. It is apparent that the elapsed time can be reduced significantly by increasing the mix bowl pressure and tubing size. Projecting this demonstration method to a 260-FL motor forward and aft dome insulation application, the following span times were estimated, assuming six segments cast with six molds:

	Hr	Shifts
Setup Time*	24	3
Cast time, fwd (600 lb ea mold)**	12	1.5
Cast time, aft (600 lb ea mold)**	12	1.5
Cure at ambient	24	3
at 135°F	48	6
Mold removal	8	1
Fill joints between segments	8	1
Clean-up Time	16	2
Total Estimated Span Time	152	19

The completed demonstration unit was cured at 135°F for 48 hr. During cure, one edge of the fiberglass mold broke loose from the case, and approximately 20 lb of material leaked out. The integrity of the segment was not affected, and only the material level in the mold was lowered. It was apparent that either a mechanical or vacuum seal would be required for future applications. The mold was removed after cure and the segment was stripped from the chamber. Radiographic inspection showed that the cured IBC-111 segment was completely free of defects. This void-free condition also was evident in the sample blocks and mechanical property specimens cut from the cured setment. Physical property values are included in Figure 5.

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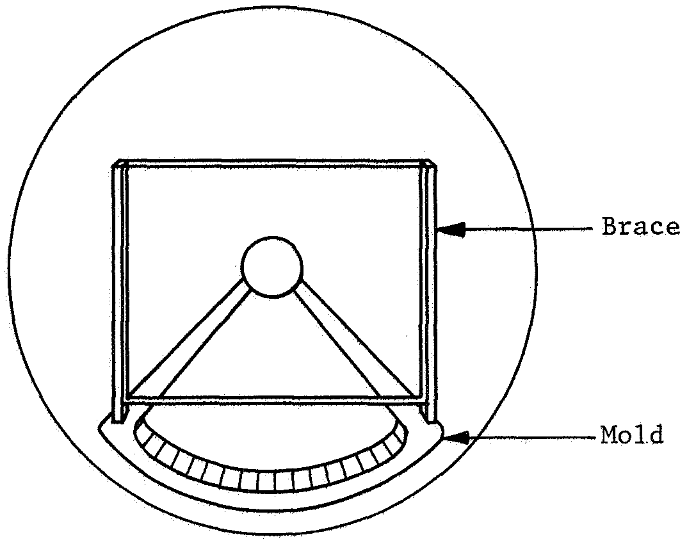
* Molds positioned at 0, 60, 120, 180, 240, and 300 degrees in both aft and forward dome.

** 2 hr/mold, or a casting rate of approximately 300 lb/hr.

IV. Process Evaluation (cont)

D. 40SD-80 DOME INSULATION DEMONSTRATION

40SD-80 was demonstrated as a castable, forward and aft head insulator. The demonstration was identical to the IBC-111 demonstration, except for mold retention. In addition to RTV-732 sealant, mechanical stiffeners or braces were wedged against the corners of the mold, as shown in the following sketch:



One hundred twenty lb of 40SD-80 were bottom cast into the fiberglass mold. The completed demonstration unit was cured for 24 hr at ambient temperature, then at 135°F for an additional 48 hr. Radiographic inspection of the cured segment showed no defects. This void-free condition was evident in the sample blocks and property specimens cut from the cured 40SD-80 segment.

Mechanical properties of 40SD-80 specimens taken from this demonstration are included in Figure 5. While IBT-100 and IBC-111 showed no marked differences in mechanical properties between large (Task II) and small (Task I) batch processing, 40SD-80, the polyurethane material manufactured by American Polytherm, showed a significant increase in hardness when processed in a 200-lb batch size. The heat generated by the material's exothermic cure reaction was observed during small batch mixing. Temperature surveillance was maintained during Task II mixing and casting to prevent any possibility of premature cure in the mixing bowl. The material temperature steadily increased to 110°F during mixing and then leveled-off at this temperature during mold casting. The large batch, as-cast material properties, though indicating a much more rigid structure than that obtained in small batch processing, are satisfactory for large motor dome insulation applications.

IV. Process Evaluation (cont)

E. IBT-106 PROPELLANT BOOT DEMONSTRATION

Installation and seaming of precured V-45 propellant boot segments in 260-SL motors were very time-consuming operations. One prime side-objective of the LMISD Program was to find a material and installation process for propellant boots that would be as reliable as the V-45 boot, while at the same time being faster and simpler to install.

Toward this end, IBT-106 was demonstrated as a trowelable, propellant boot material. Mixing was accomplished in a 30-gal Baker-Perkins vertical batch mixer, and fed from the mixing bowl, through the bottom draw-off using a pressure diaphragm, into the forward dome of the motor.

The interior surface of the 54-in.-dia chamber forward dome was released with DC-Q-92. The purpose of the release was to facilitate removal of the cured material for inspection. Also, installation of a propellant boot in an actual motor will be against a released insulation surface.

The entire forward dome of the motor was covered with 0.25-in.-thick material. The thickness was controlled by a manual template/trowel mounted in the forward boss of the dome, as shown in Figure 11. The actual trowel used is shown in Figure 12.

Various views of the cured IBT-106 propellant boot are shown in Figures 13, 14 and 15. Several small defects were visible in the backside surface which was in contact with the released dome. During application the IBT-106 material tended to adhere to the trowel surface and subsequently pulled away from the released surface, resulting in the noted surface defects. Close inspection showed that the defects were only on the surface, and did not penetrate into the material. However, every effort must be made to eliminate propellant boot defects, no matter how minor they may be. Two process changes were indicated. First, the width of the trowel surface which is in contact with the material should be smaller. In this way, the tendency to pull or drag material away from the released chamber surfaces will be reduced. Second, the amount of material allowed to build-up in front of the trowel should be reduced. For this demonstration, material was fed into the dome through a 1.0-in.-dia nozzle. Accumulated material made it difficult for one operator to move the trowel. Thus it was necessary to remove excess material. In so doing, the material build-up in front of the trowel was uneven and not in intimate contact with the released chamber surface.

The overall demonstration results were encouraging, and it was apparent that this method of propellant boot installation offered significant raw material, handling, and installation labor cost savings.

IV. Process Evaluation (cont)

F. COMPOSITE IBT-100 DOME/IBT-106 BOOT DEMONSTRATION

The encouraging results of the IBT-106 propellant boot demonstration led to the recommendation that a composite dome insulation and propellant boot installation be evaluated. This recommendation was approved by the NASA/LeRC Project Manager.

IBT-100 was demonstrated as a trowelable, forward dome insulator, to be followed by installation of an IBT-106 propellant boot. This demonstration was a combination of the previous IBT-100 and IBT-106 demonstrations. The objective was to demonstrate the installation processes that would be used to insulate a large rocket motor, which would include both dome insulation and propellant boot installation.

One-200 lb batch of IBT-100 was processed in a 30-gal Baker-Perkins vertical batch mixer. IBT-100 was forced from the mixing bowl through the bottom draw-off, and was pressure fed through a nozzle into the head of the motor.

As shown in Figure 16, one-half of the dome section was insulated. The thickest section was 2.0-in., tapered to 0.5 in. at the sidewall. The contour was controlled by a manually operated trowel mounted in the forward boss of the dome. A pneumatic vibrator was attached to the trowel to permit smoother movement of the insulating material. When installation was complete, the material was cured at ambient temperature for 48 hr, followed by a 48 hr cure at 135°F. The completed demonstration is shown in Figure 17.

After cure, the insulated dome was removed from the oven. A release coat of DC-Q-92 was installed over the IBT-100 surface, as shown in Figure 18. As shown in Figure 16, IBT-106 material was troweled into a 5.0-in.-long adjacent sidewall section and over the released IBT-100 insulation surface as a 0.25-in.-thick propellant boot. The trowel configuration and material distribution techniques used reflected the changes described previously. The completed demonstration is shown in Figures 19, 20 and 21. The propellant boot was cured for 24 hr at ambient temperature, followed by 48 hr at 135°F. There were no defects observed in the IBT-106 boot. The composite process evaluation was successful, and showed that this technique of dome insulation and propellant boot installation is attractive for large motor insulation system applications. The completed demonstration will be retained for use in evaluating potential NDT inspection techniques during conduct of Contract NAS3-12036.

Based on this demonstration, the following span times were estimated for 260-FL motor forward and aft propellant boot installation:

IV.F. Composite IBT-100 Dome/IBT-106 Boot Demonstration (cont)

	Hr	Shift
Setup Time	8	1
Fwd Boot Installation	24	3
Aft Boot Installation	32	4
Cure at Ambient	24	3
at 135°F	48	6
Clean-up Time	16	2
Total Span Time	152	19

G. IBS-107 AND IBS-109 SIDEWALL INSULATION DEMONSTRATION

Enginering representatives of The DeVilbiss Company, San Jose, California, were contacted regarding the feasibility of spraying IBS-107, IBS-109, and Avcoat II as sidewall insulation and propellant boots. Equipment availability also was discussed. The DeVilbiss Company had been involved previously in development work concerning spray-application of IBS-109 as 2.75-in.-rocket case insulation. Poor results were obtained using spray techniques. Spray performance of IBS-109 was improved with solvent addition and application of heat (180°F) to the feed line. The spinning-disc spray technique of IBS-109 insulation was selected eventually for the 2.75-in. motor. Aerojet provided DeVilbiss with two 1-gal kits of IBS-107 and IBS-109. The materials were evaluated in their San Jose facility for feasibility of spray applications. Avcoat II was not included in this evaluation because of its poor erosion resistance in the Task III test motor.

After several unsuccessful attempts, a satisfactory test panel of IBS-109 was obtained and delivered to Aerojet for evaluation. The IBS-109 test panel (6-in.-wide by 12-in.-long) was applied with two vertical passes from a DeVilbiss Model JGA-502-777E spray gun, with a 0.070-in.-dia orifice-nozzle. The IBS-109 material was mixed in accordance with Aerojet instructions. The IBS-109 material viscosity then was reduced by mixing into a 30 percent solution with trichlorethylene solvent and preheating to 190°F. The material tended to sag slightly after application; to prevent sagging, the DeVilbiss engineer recommended reducing the preheat temperature to 150°F. The data sheets prepared by DeVilbiss for the IBS-109 test panels are shown in Figures 22, 23, and 24. The test panel experiments were repeated using IBS-107 material.

Engineers from the DeVilbiss Company's San Jose Laboratory demonstrated spray application of IBS-107 and IBS-109 in the 54-in.-dia chamber.

IV.G. IBS-107 and IBS-109 Sidewall Insulation Demonstration (cont)

Two gallons of IBS-109 and IBS-107 were processed. After mixing, the IBS-109 material viscosity was reduced by addition of 0.6-gal of methyl-ethyl-ketone solvent. IBS-107 material viscosity was reduced with trichloro-ethylene. Material was fed under pressure through the heat-exchanger into the spray gun. As shown in Figure 25, the feed line from the heat-exchanger to the gun was water jacketed. Material temperature at the spray gun was 160°F. The hot water was recycled back into the heat-exchanger. Photographs of the DeVilbiss Company spray demonstrations are shown in Figures 26, 27, and 28.

IBS-109 was applied to the chamber sidewall in an area approximately 12-in.-wide spanning one-half of the circumference to a thickness of 0.25-in. Approximately 30-min after application, the material near the vertical began to sag, and eventually slumped to the bottom of the chamber.

IBS-107 was applied to the sidewall to a thickness of 0.05-in. After application, the sprayed area was rotated to an overhead position and allowed to set overnight. No slump or sag was observed. However, some of the material had dripped to the bottom of the chamber.

Three conclusions were gathered from these demonstrations. First, multiple applications of sprayable material are required, with at least a 24-hr ambient gel time between applications. Thicknesses of 0.05 to 0.07 can be sprayed at each application. Second, continual chamber rotation during gel and cure is required to prevent material running or dripping. Third, the solvent used to reduce material viscosity is flashed-off during the spray operation, so that the material applied to the sidewall essentially is free of residual solvents.

Spray application of sidewall and propellant boot material appears to be a feasible installation technique, and is well suited for automation. There are two distinct disadvantages. First, multiple applications are required, with sufficient gel or cure time allowed between applications to prevent slump or sag. Second, continual chamber rotation during gel and cure is required. These disadvantages become only minor inconveniences if the motor insulation system installation operations are not pacing the overall motor processing operations.

H. TI-H704B DOME/SIDEWALL INSULATION DEMONSTRATION

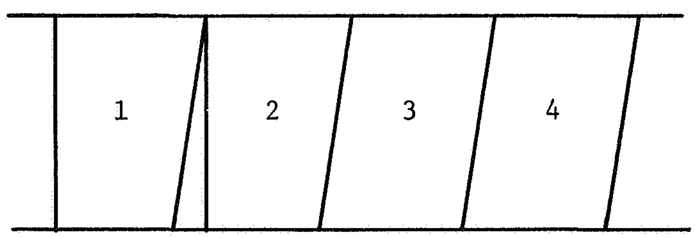
TI-H704B was mixed in accordance with the Thiokol Chemical Corporation material specification and troweled into the forward dome of the 54-in.-dia test chamber. The installation procedure was the same as that previously used for IBT-100 installation. Difficulty was encountered in moving the material into the desired configuration, particularily in the 4.0-in.-thick section. Also, the material adhered to the trowel, and in so doing, IV.H. TI-H704B Dome/Sidewall Insulation Demonstration (cont)

continually pulled away from the dome surface. Using small hand trowels in conjunction with the regular dome trowel, a satisfactory segment of TI-H704B dome insulation was obtained. Experience gained in this demonstration clearly shows that a pneumatic tamping process is required for installation of TI-H704B material.

I. IBT-106 SIDEWALL INSULATION DEMONSTRATION

This demonstration essentially was a repeat of the first Task II sidewall demonstration. Two aspects of this process evaluation were different. First, a spiral pattern was used to demonstrate that sidewall insulation could be applied continuously, without stopping to move the trowel to an adjacent position. Second, the sides of the trowel were modified to minimize the ridge of insulation material formed between adjacent passes. One undesirable result of the first IBT-106 sidewall demonstration was the thickness variation encountered at the joint between adjacent passes.

IBT-106 material was pressure-fed from the mix bowl into the annulus of the trowel, as shown in Figures 29 and 30. The trowel gap was set to control the insulation thickness to 0.25-in. As shown in Figures 29 and 30 and in the following sketch, an initial circumferential pass was made, followed by three spiral passes:



Approximately a 0.5-in. overlap was maintained between adjacent passes. A 0.5-in.-high ridge of material was formed at the joint between adjacent passes and was significantly smaller than the ridge formed during the first demonstration. Material was applied by holding the trowel in a fixed position against the sidewall while manually rotating the chamber on the turning rolls. The material was cured for 24 hr at ambient followed by 48 hr at +135°F. There was no evidence of slump or sag during cure. After cure, the ridges were removed. The completed demonstration is shown in Figure 31. The cured sheet was stripped from the released chamber and cut into 12-in. sections. Thickness continuity ranged from 0.20 to 0.25-in., well within the acceptable tolerance allowed for sidewall applications. As concluded previously, this method of installing sidewall insulation appears desirable, and can be improved significantly by using constant-speed, motor driven turning rolls.

V. CONCLUSIONS

Based on the results of this Task II effort, there are several attractive, low-cost insulation systems which are applicable to various sections of the 260-FL motor. These candidate insulation systems are summarized in Figure 32. It was not the objective of this program task to select the system most applicable to large motors. This selection will be made during the Task IV effort. The Task II effort was to determine if a given material could be installed economically. In addition, span times, repair techniques, tooling, and cost-influencing factors were to be identified. The following paragraphs summarize the results of the various material process evaluations.

A. IBT-100 TROWELABLE DOME INSULATION

IBT-100 previously was used in Motor 260-SL-3 as a trowelable nozzle shell insulation material. Installation was accomplished without incident, and material performance met the design requirements. The 260-SL-3 experience coupled with the experience gained during this task effort indicates that trowelable IBT-100 is an acceptable insulation material for large motor applications. Tooling involves a sweep template/trowel and a spider support mounted on the motor processing truss beam. The sweep template also will serve as an inspection tool. Repair of the cured IBT-100 can be accomplished, as the bond strength of uncured-to-cured material exceeds the propellant-to-liner bond strength. Mechanical properties are not affected by large batch mixing. Estimated span times for IBT-100 material dome installation are less than those for a V-44 system, as shown in Figure 33.

B. IBC-111/40SD-80 CASTABLE DOME INSULATION

These materials have no previous use history in large motors. The process evaluation results show that both materials can be bottom-cast into the motor dome sections. The void-free condition of the specimens testify to the material integrity that can be obtained with this installation process. The tooling requirements involve a six-segment mold, with either a vacuum or mechanical retention capability. Repair capability of both materials is acceptable. The mechanical properties of IBC-111 are not affected by large batch mixing. 40SD-80 on the other hand shows a significant hardness increase due to the exothermic cure reaction in large batch sizes. The material hardening does not interfere with its use in large motor applications. However, the short pot-life of 40SD-80 could present processing problems if a delay is encountered during the casting operation.

V. Conclusions (cont)

C. IBT-106 TROWELABLE SIDEWALL INSULATION

The acceptable processing characteristics of IBT-106 as sidewall insulation was an unexpected bonus. Previously it was thought that this material was too viscous for sidewall (and propellant boot) applications. However, the adaptation of the liner trowel for this application provided a satisfactory and consistent method of material distribution. Constant speed, motor driven turning rolls; a light-weight, portable material holding pot; and a weighted, mobile trowel are the required tooling. Repair of either uncured or cured sidewall material is acceptable. The mechanical properties of IBT-106 are not affected significantly by large batch mixing. As shown in Figure 33, the estimated span time for sidewall installation of IBT-106 is less than that required for secondarily bonded V-44.

D. IBT-106 TROWELABLE PROPELLANT BOOTS

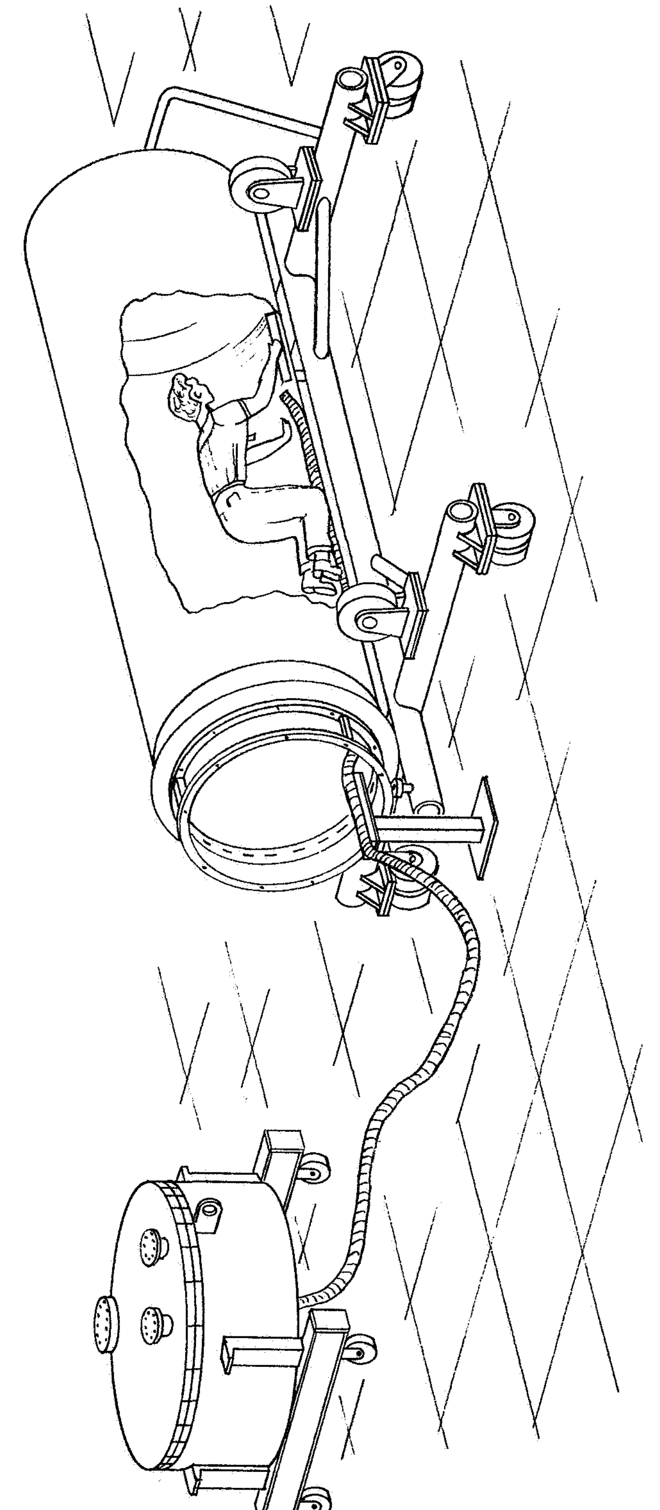
Troweling IBT-106 over released dome insulation appears to be a faster and simpler method of propellant boot installation than using precured V-45 components. Predicted reliability is unaffected. Tooling requirements include both a forward and aft sweep template/trowel, and vacuum bags for boot retention during movement and propellant loading.

E. IBS-107/IBS-109 SPRAYABLE SIDEWALL INSULATION

Process evaluations with sprayable IBS-107 and IBS-109 materials in large motors show that, while this technique offers potential production cost reduction, more development work is necessary. Results of this program showed that multiple applications, with at least a 24 hr cure time between applications, are required to build-up insulation thicknesses greater than 0.10-in. without slump or sag. Continual chamber rotation during cure also is required.

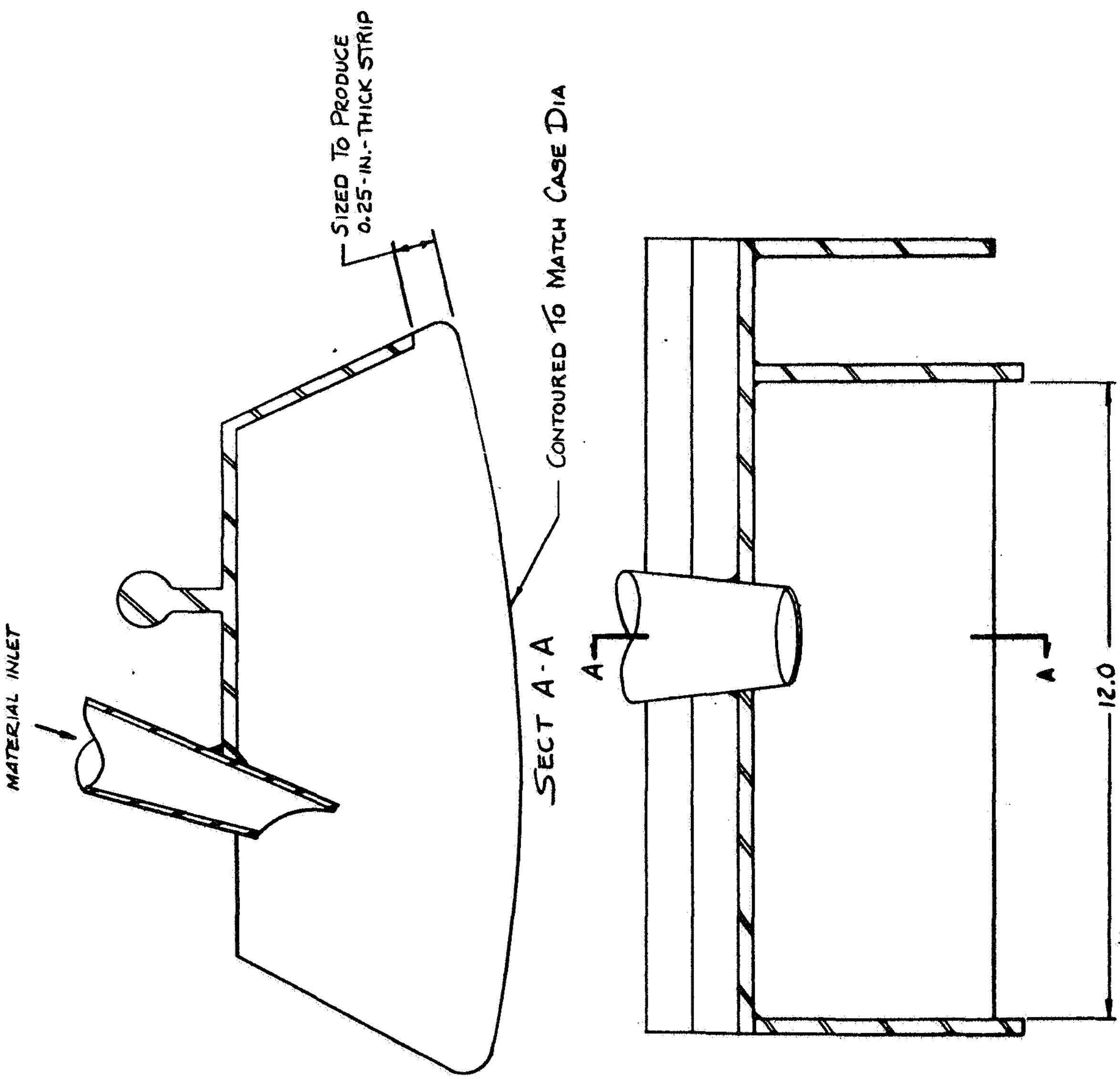
F. TI-H704B TROWELABLE INSULATION

Process evaluation of TI-H704B shows that sweep template type troweling techniques will not work with this material. TI-H704B material was used successfully by TCC in two 156-in.-dia motors. A special pneumatic tamping process appears to be the only practical installation process for TI-H704B.



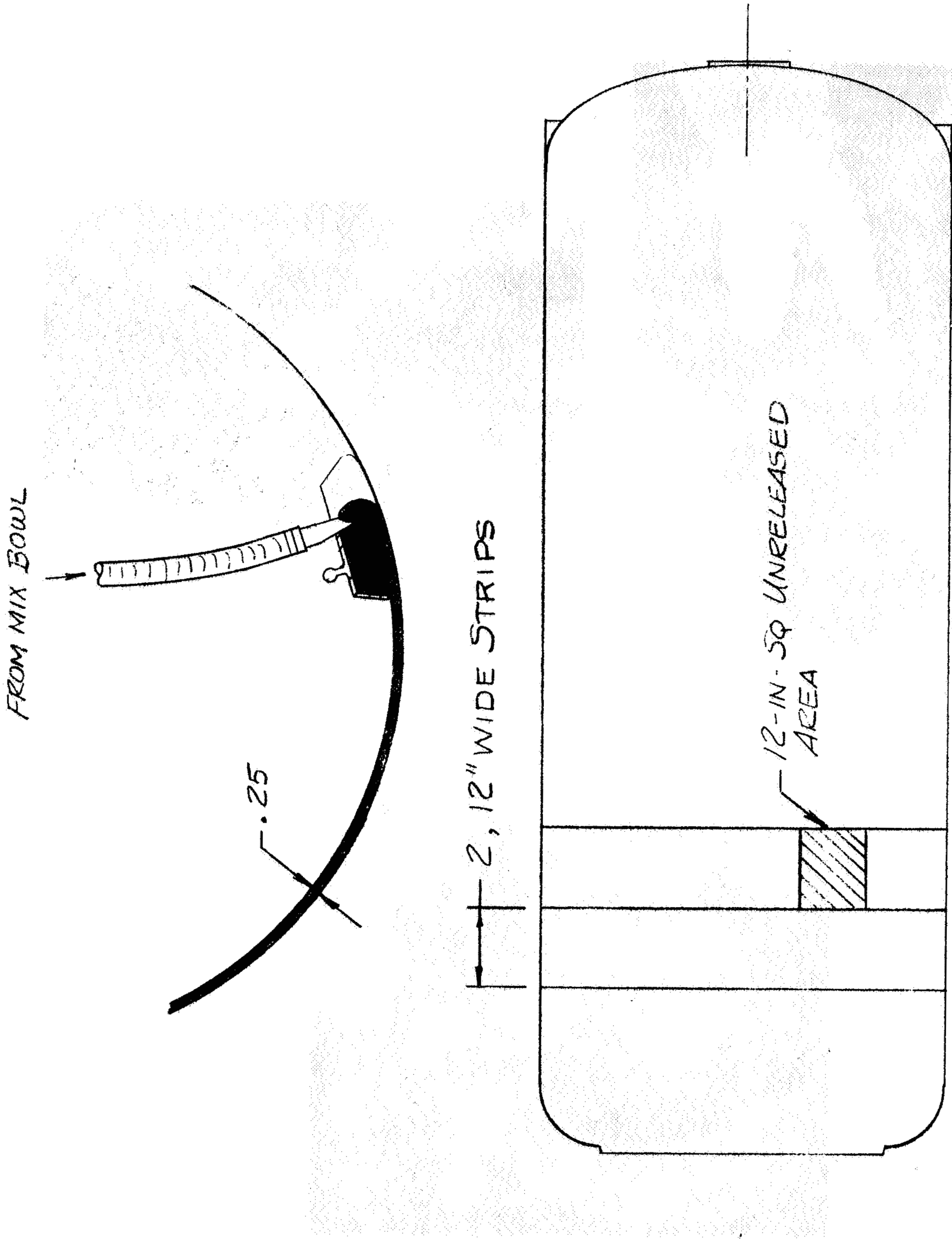
IBT-106 Demonstration Setup

Figure 1



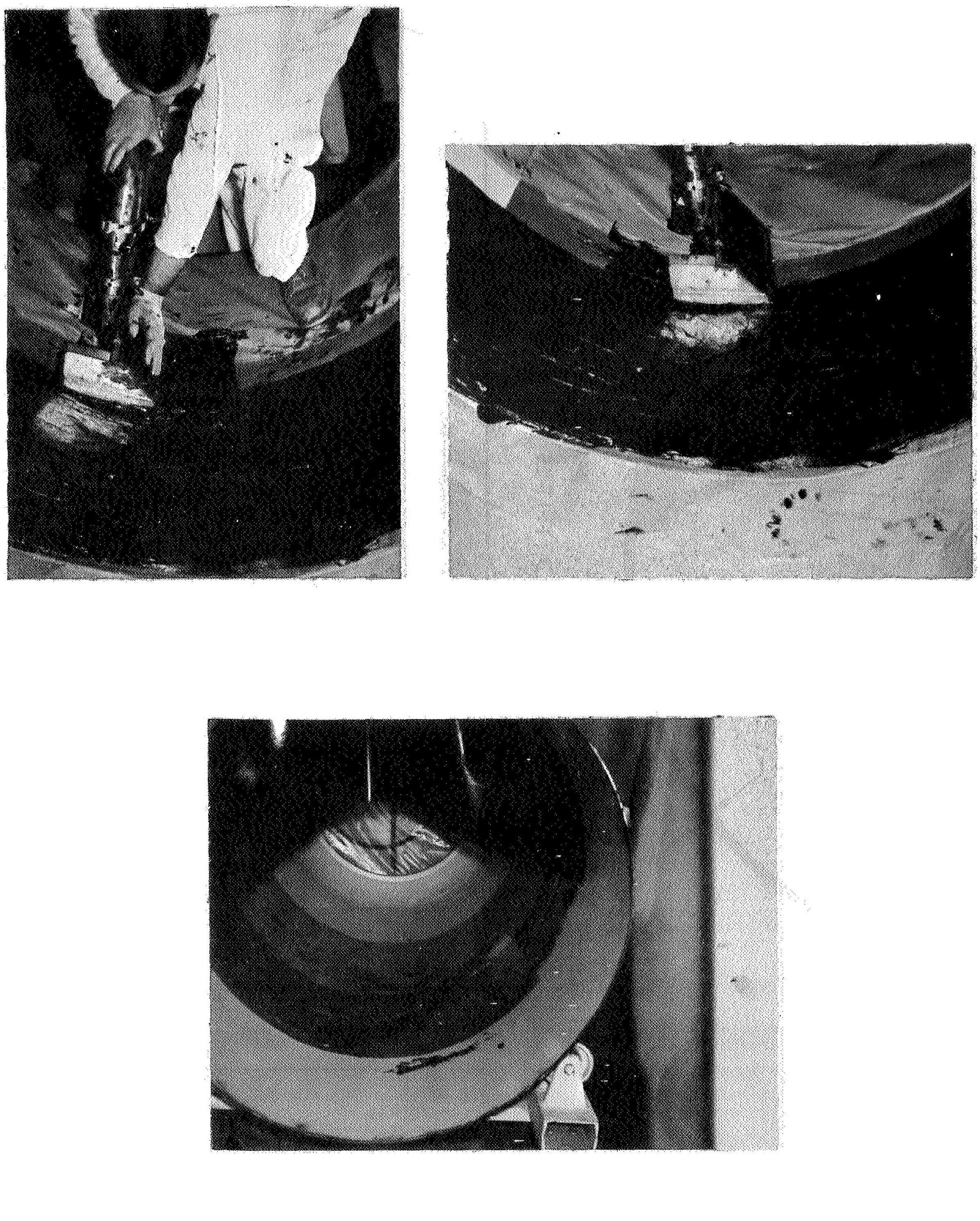
Trowel Configuration for Sidewall Insulation Demonstraton

Figure 2



Sidewall Insulation (IBT-106) Demonstration

Figure 3



IBT-106 Sidewall Insulation Process Evaluation

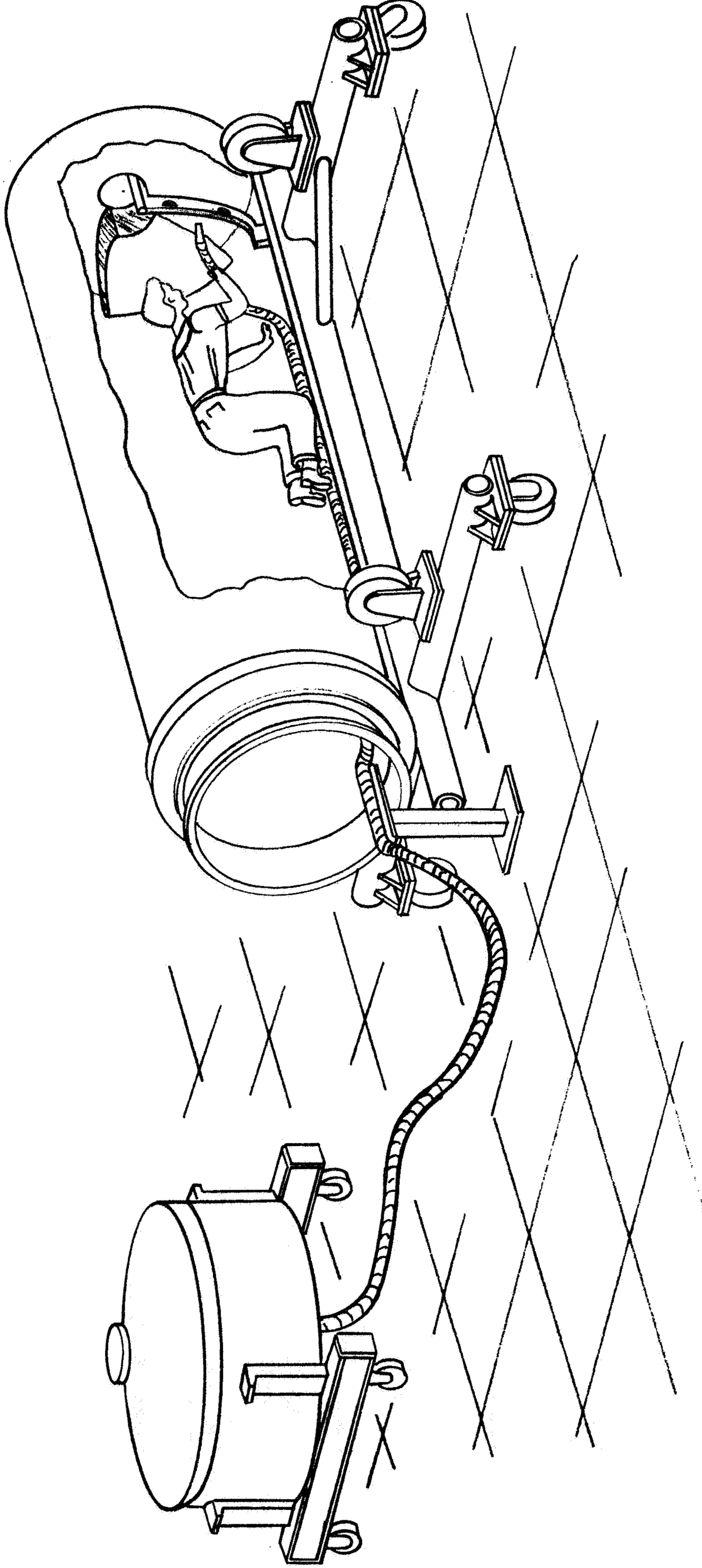
Figure 4

	IBT-100			IBC-111			40SD-80		
	Specimen from Task II Demon.	Task I Prop'ty Meas. Tests	Values Quoted by Supplier	Specimen from Task II Demon.	Task I Prop'ty Meas. Tests	Values Quoted by Supplier	Specimen from Task II Demon.	Task I Prop'ty Meas. Tests	Values Quoted by Supplier
Max.Tensile Strength,psi	870	866	866	629	-	521	2100	865	800
Tensile Strength at Break, psi	856	-	-	601	-	-	2090	-	-
Elongation at Max. Tensile Strength, %	71	59	69	63	-	93	22	80	180
Elongation at Break, %	74	61	-	66	-	-	37	83	-
Initial Modulus, psi	2817	3900	3900	2075	-	1245	27,251	2364	-
Shore "A" Hardness	79	90	-	76	-	69	93	54	-

	IBT-106		
Maximum Tensile strength,psi	2250	836	1640
Tensile Strength at Break, psi	-	-	-
Elongation at Max. Tensile Strength, %	66	36	69
Elongation at Break,%	71	37	-
Initial Modulus, psi	12,865	8873	11,500
Shore "A" Hardness	-	89	-

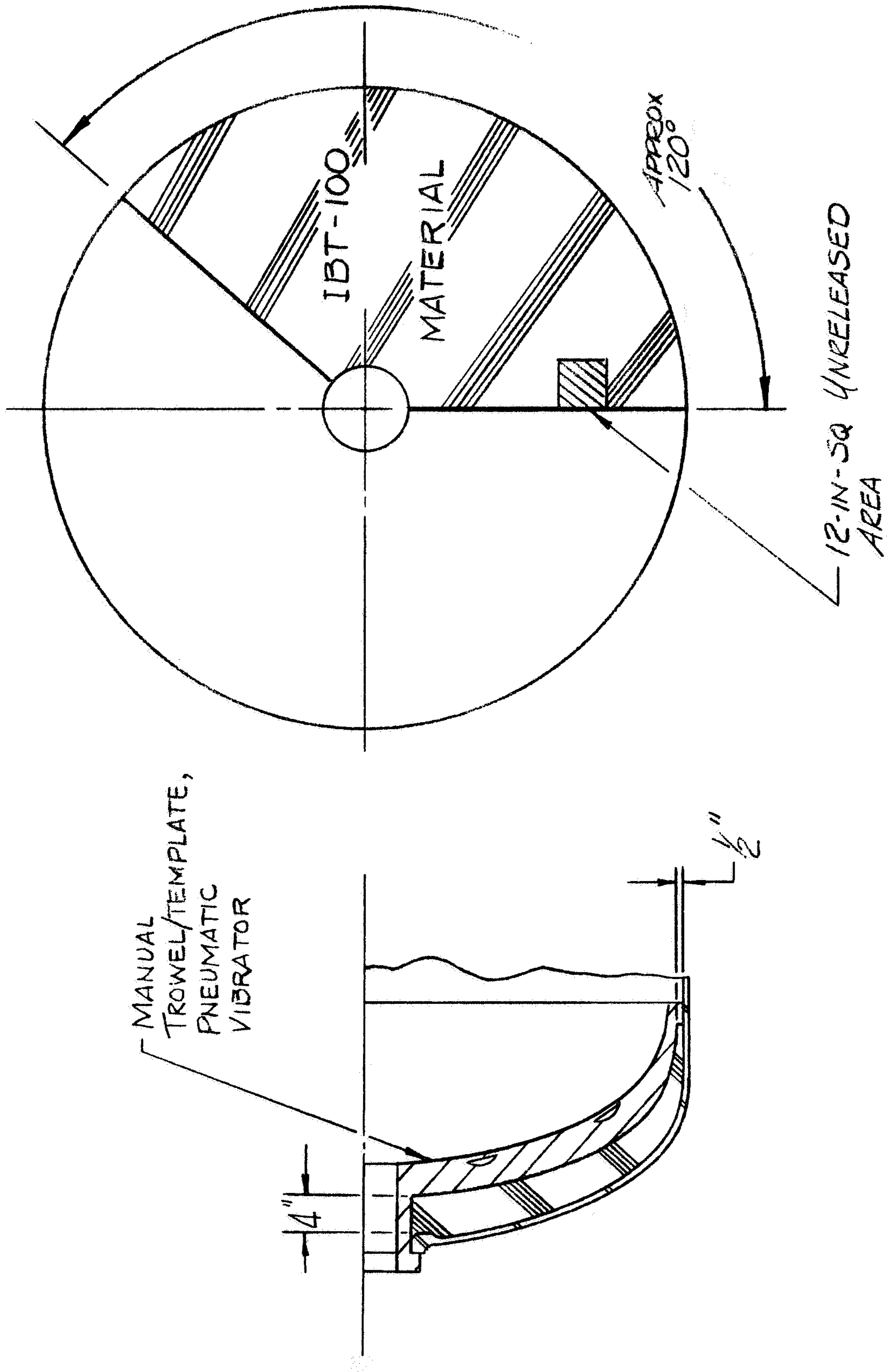
Mechanical Properties of Specimens Taken from Process Demonstrations of IBT-106, IBT-100, IBC-111, and 40SD-80

Figure 5



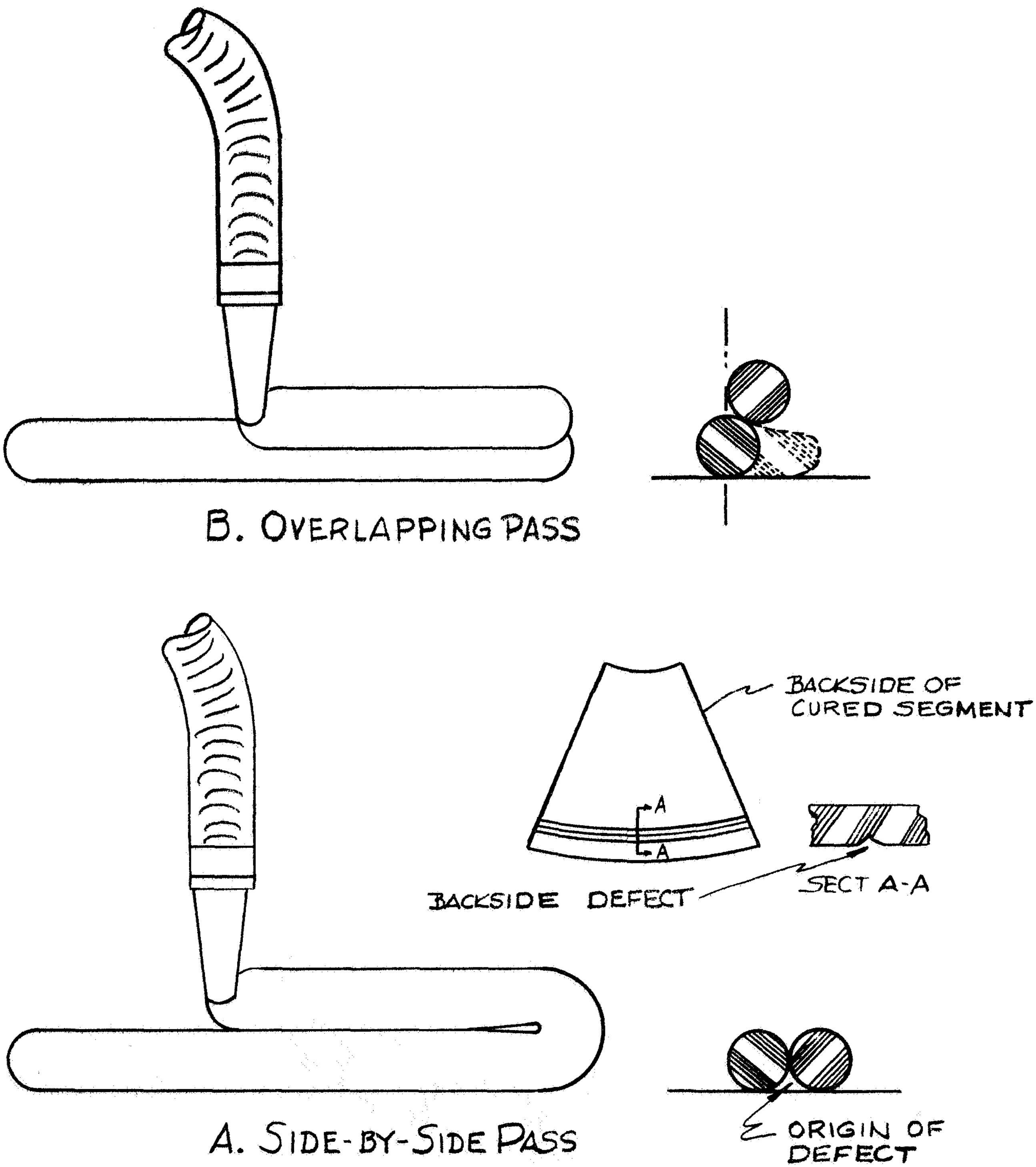
IBT-100 Demonstration Setup

Figure 6



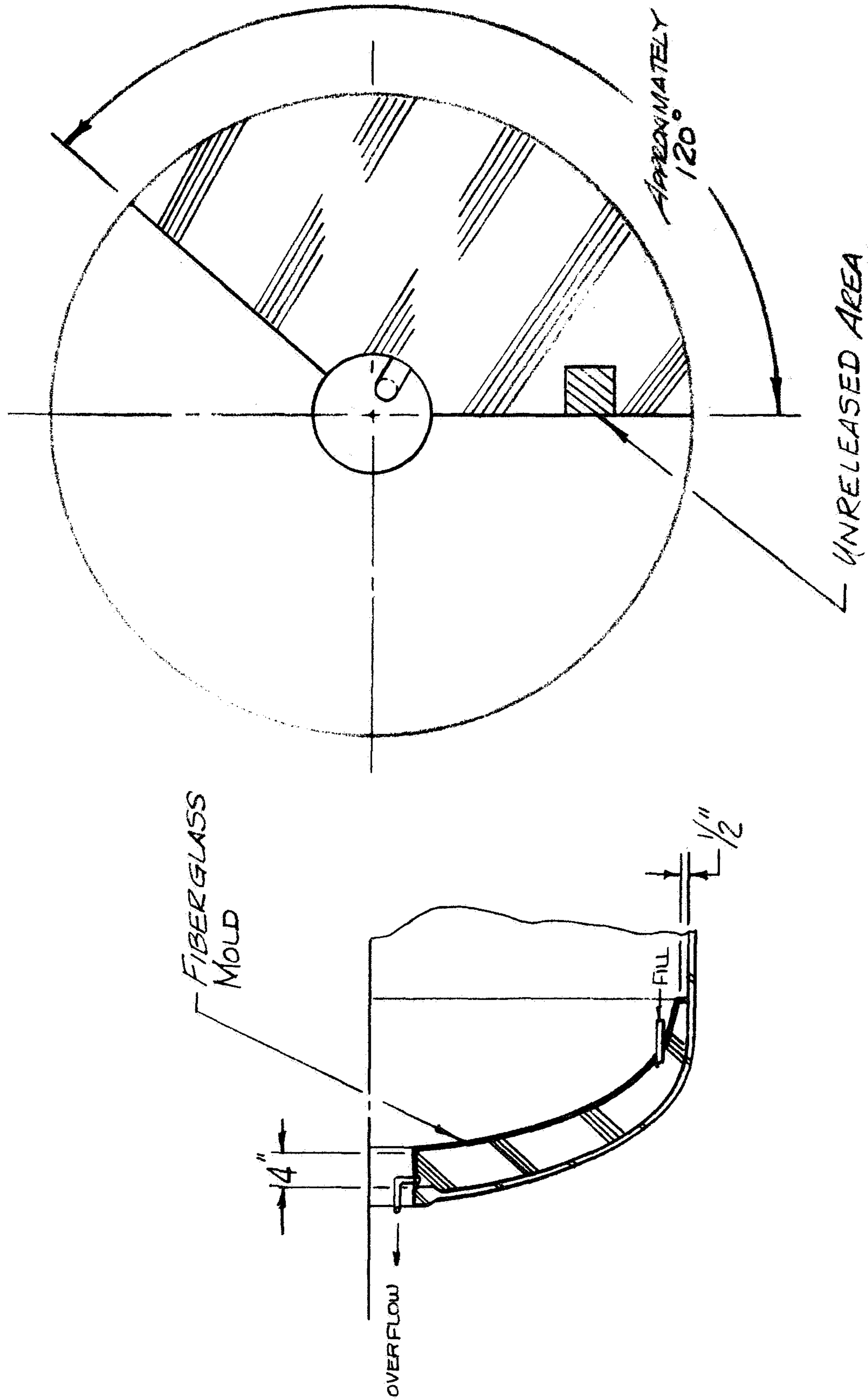
IBT-100 Demonstration

Figure 7



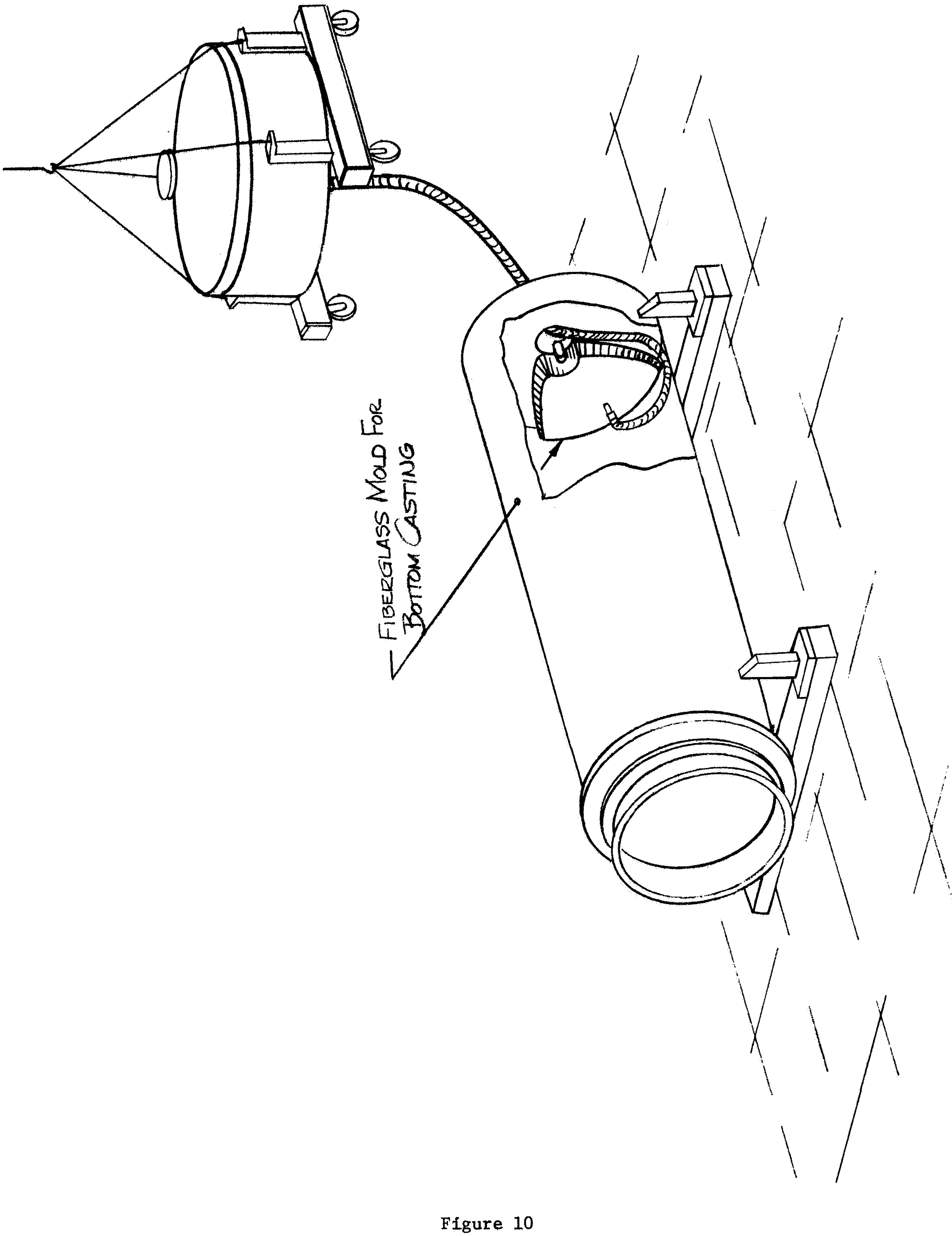
Methods of IBT-100 Installation During Demonstration

Figure 8



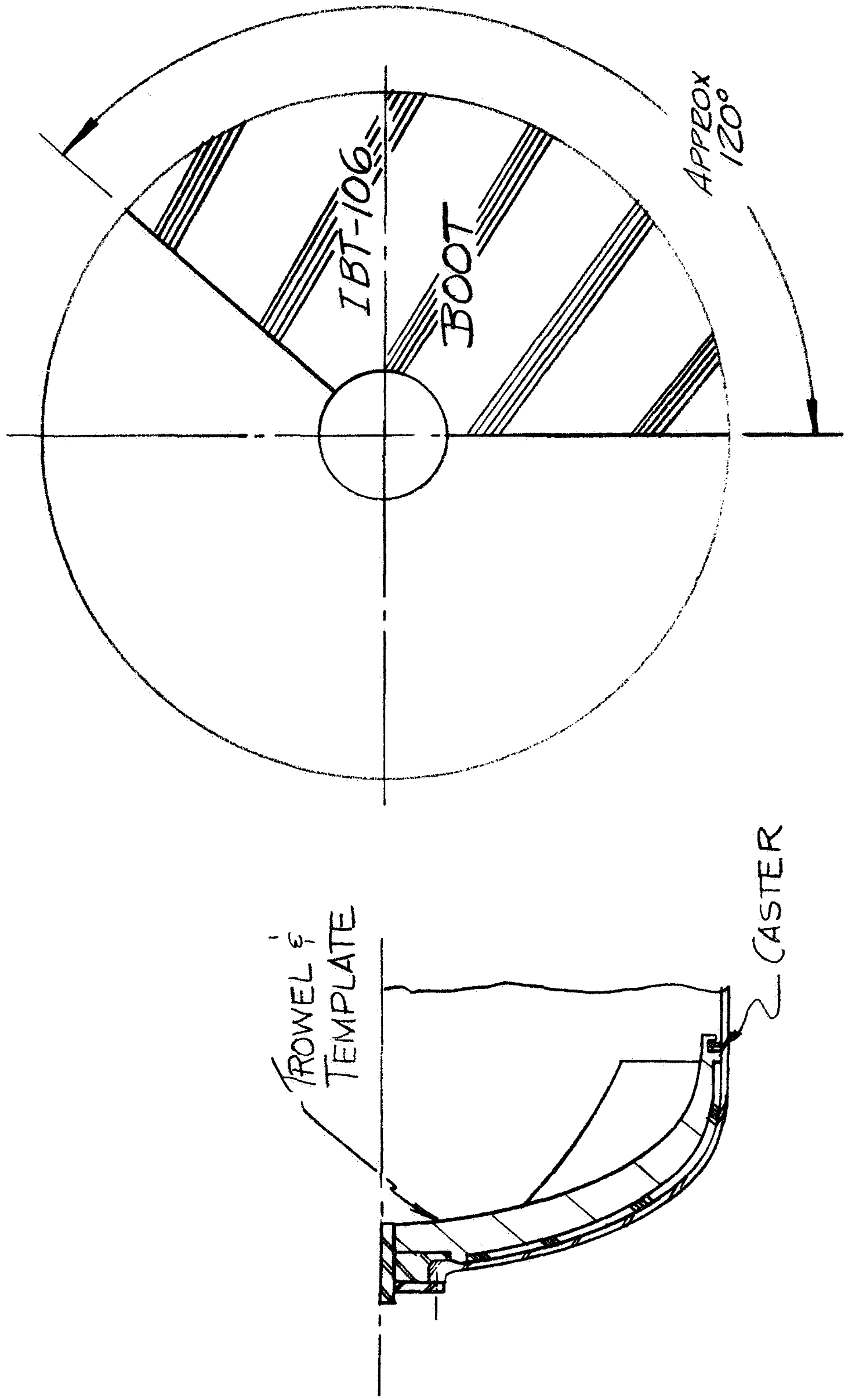
IBC-111 and 40SD-80 Demonstration

Figure 9



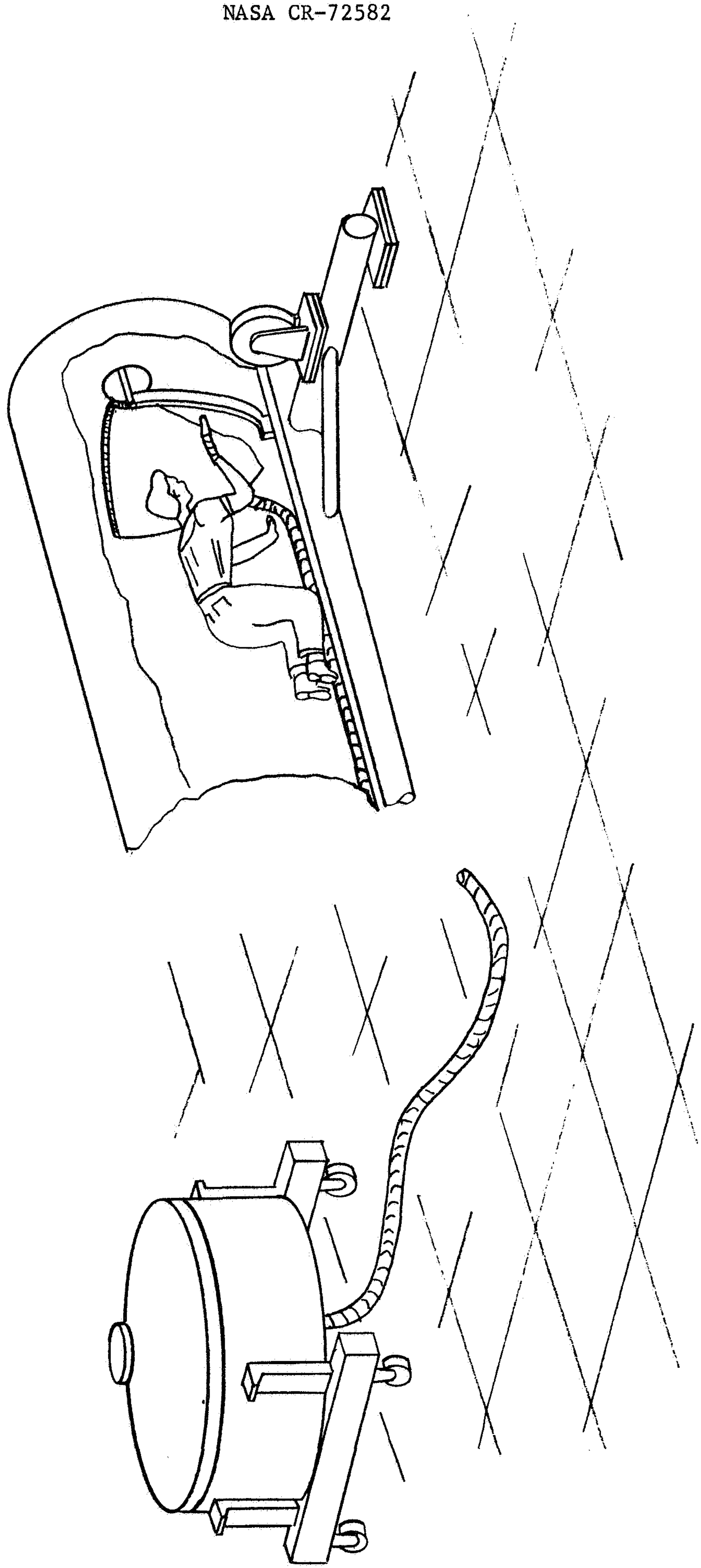
IBC-111 and 40SD-80 Demonstration Setup

Figure 10



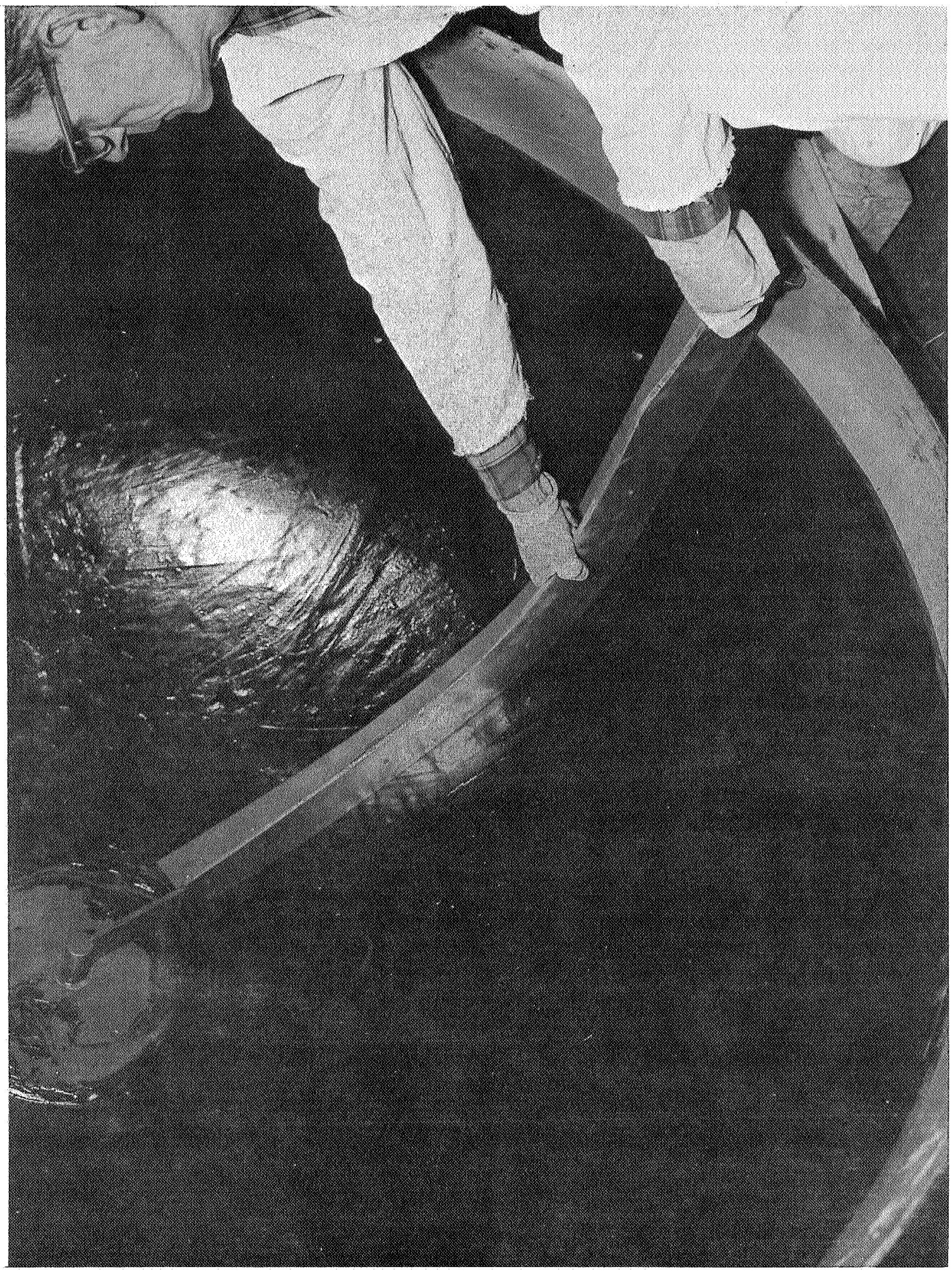
IBT-106 Boot Demonstration

Figure 11, Sheet 1 of 2



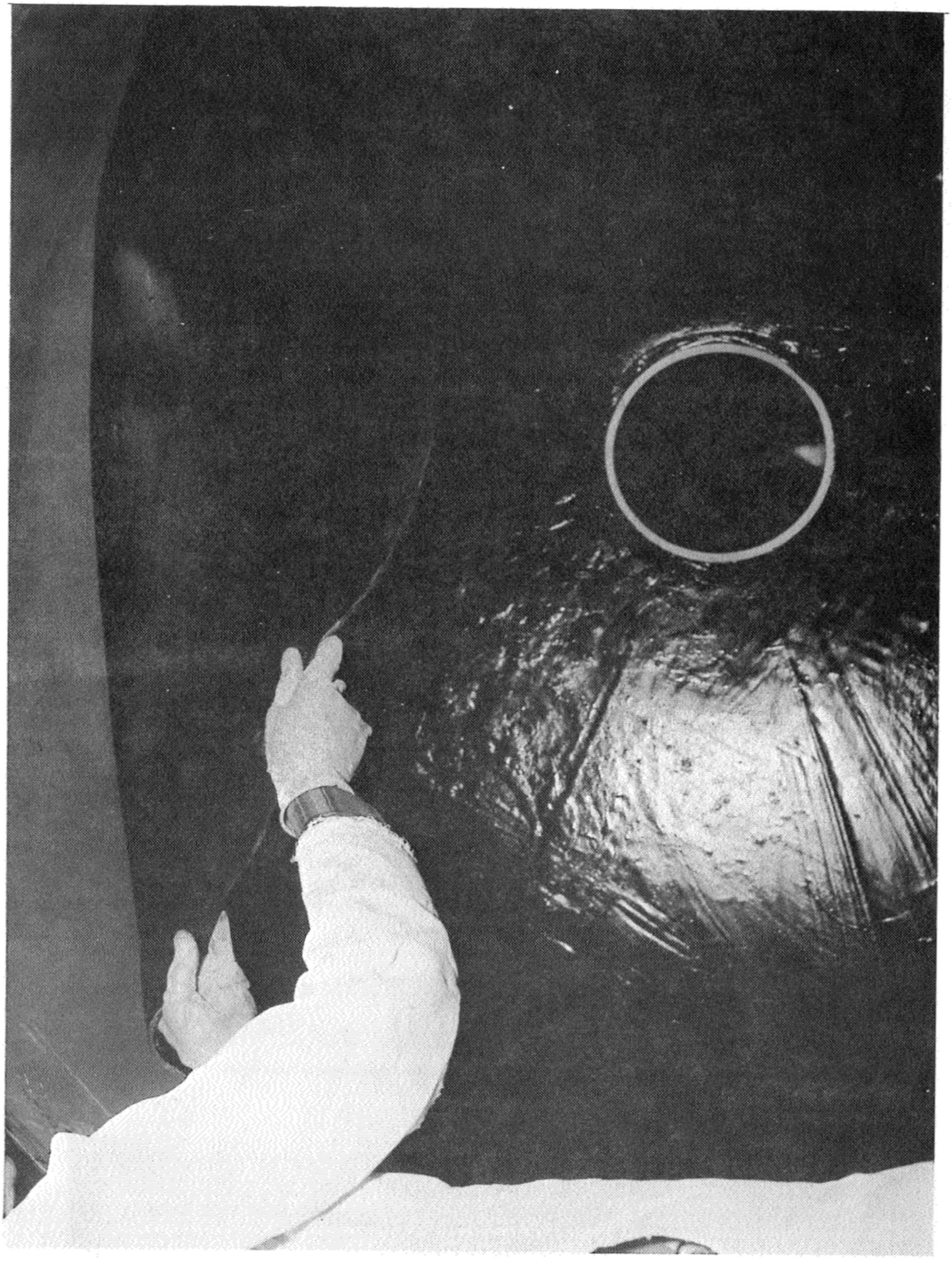
IBT-106 Boot Demonstration

Figure 11, Sheet 2 of 2



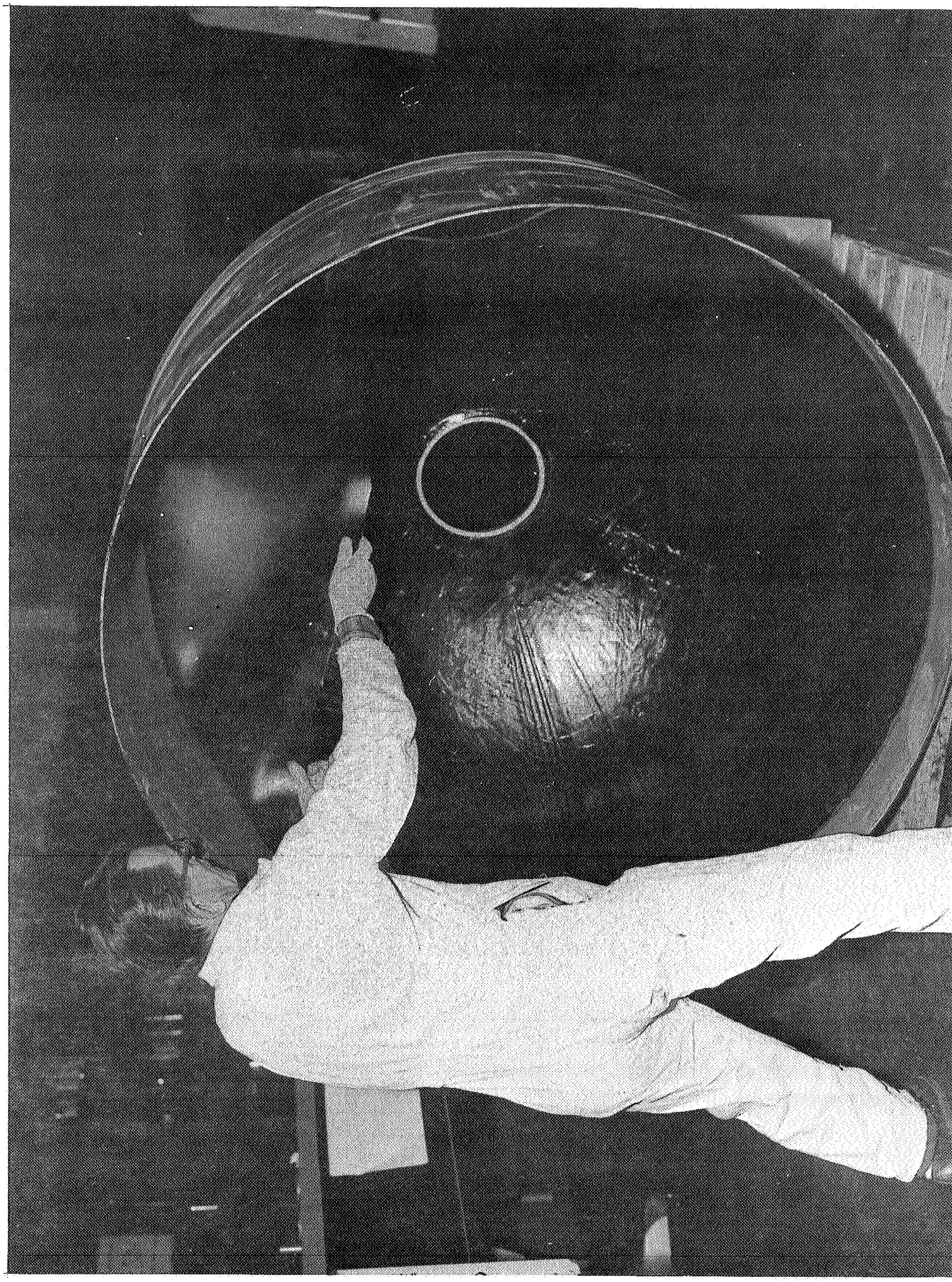
Trowel Configuration for IBT-106 Boot Demonstration

Figure 12



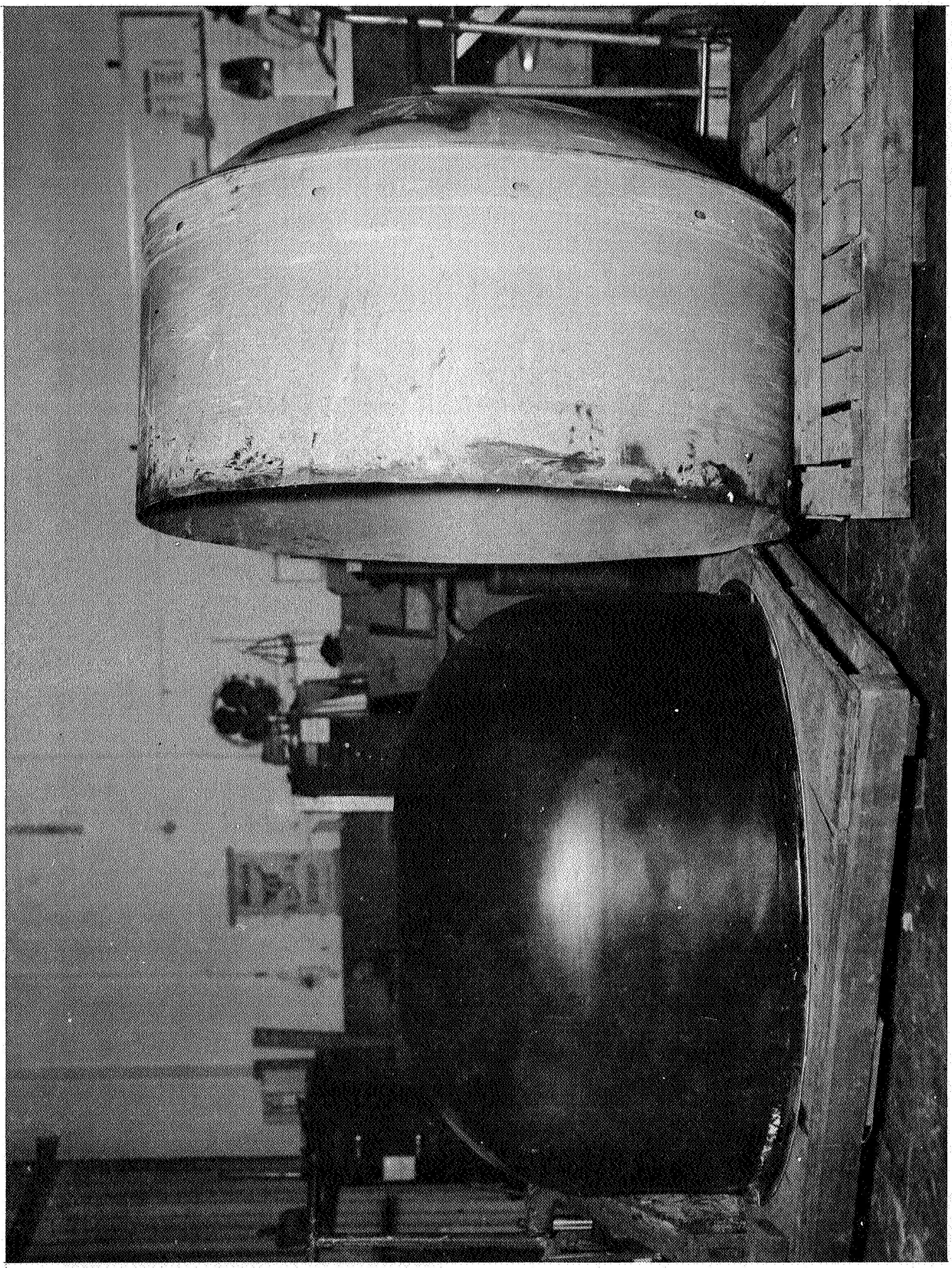
IBT-106 Propellant Boot Demonstration

Figure 13



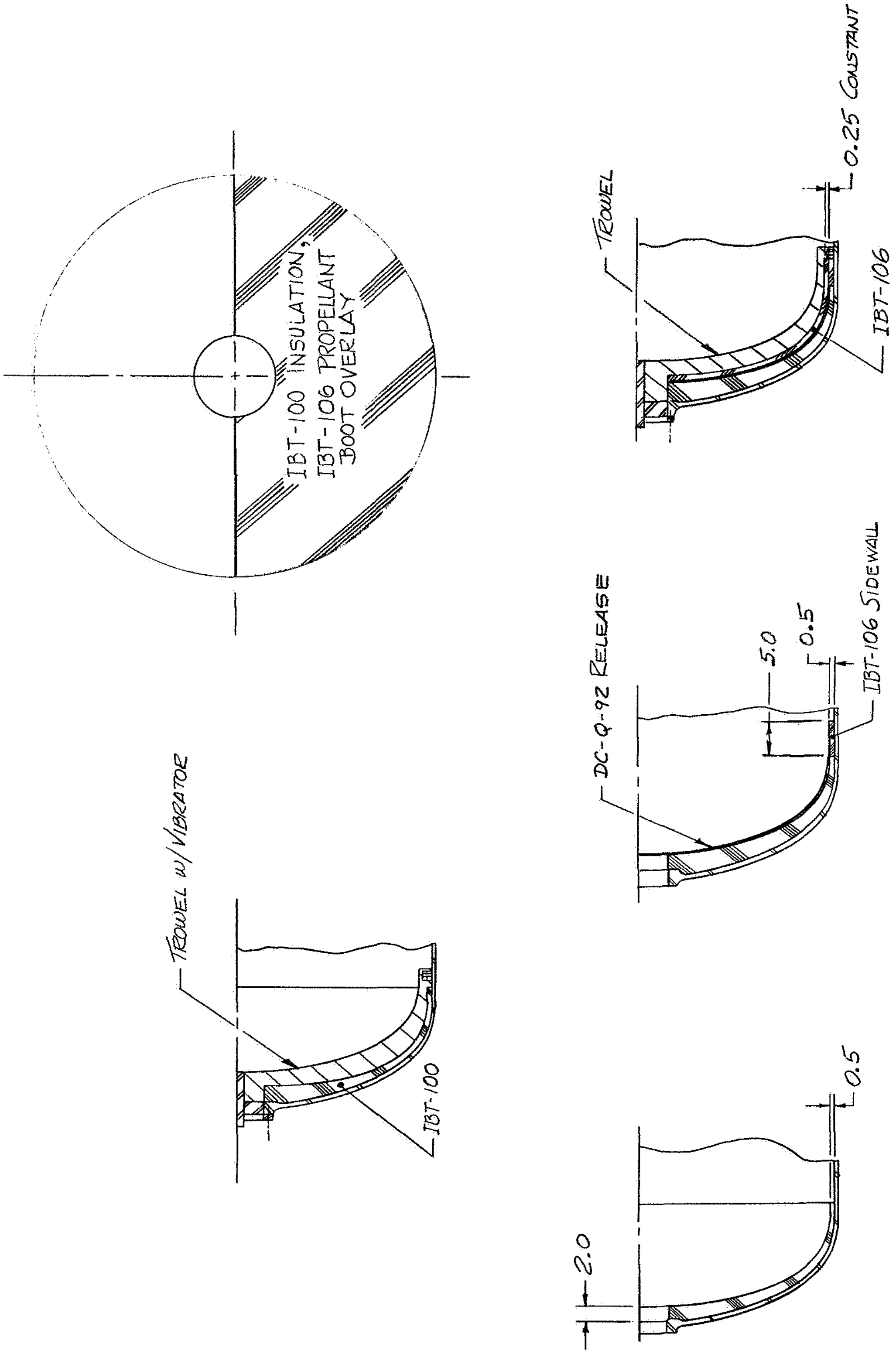
IBT-106 Propellant Boot Demonstration

Figure 14



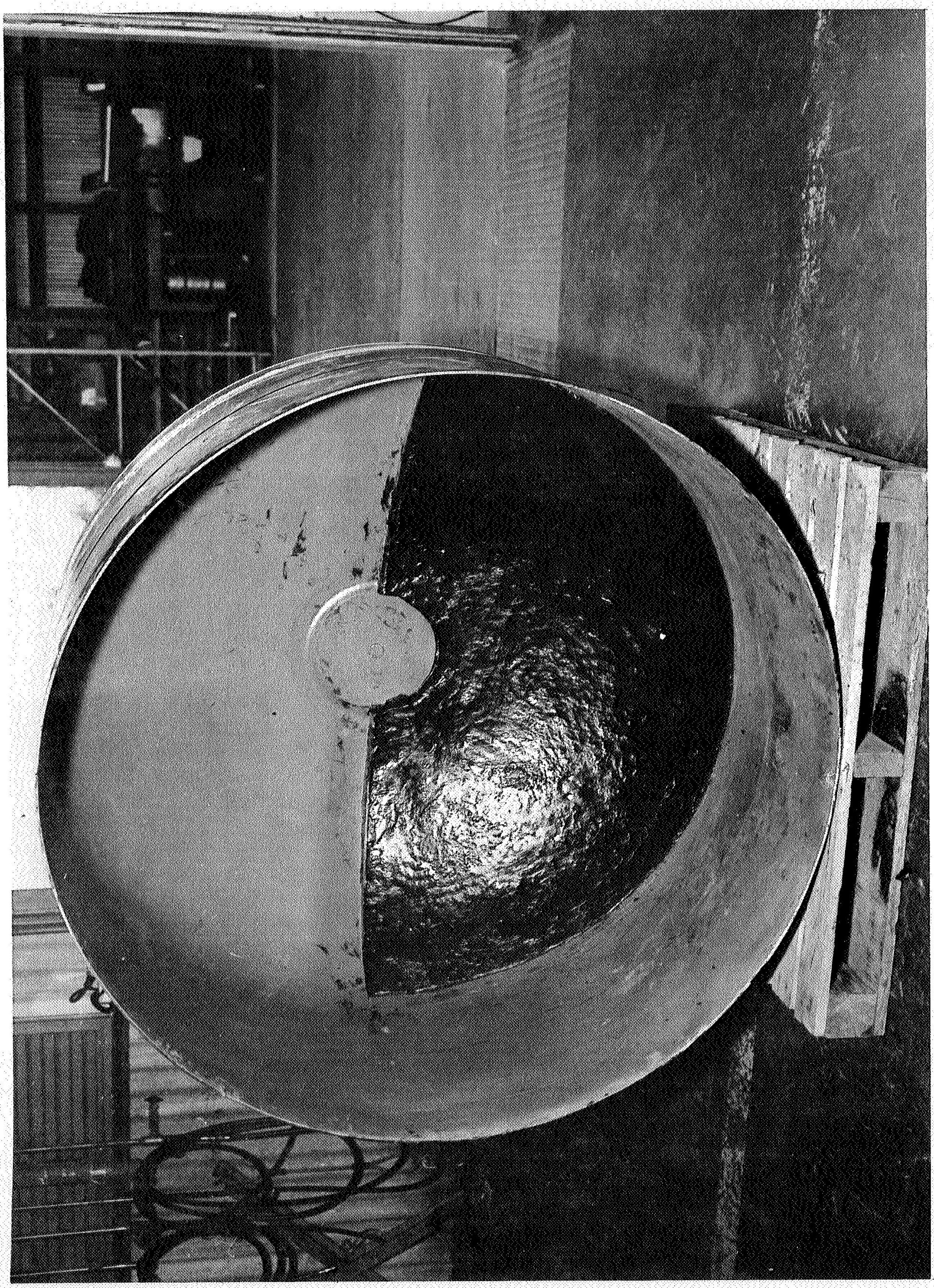
IBT-106 Propellant Boot Demonstration

Figure 15



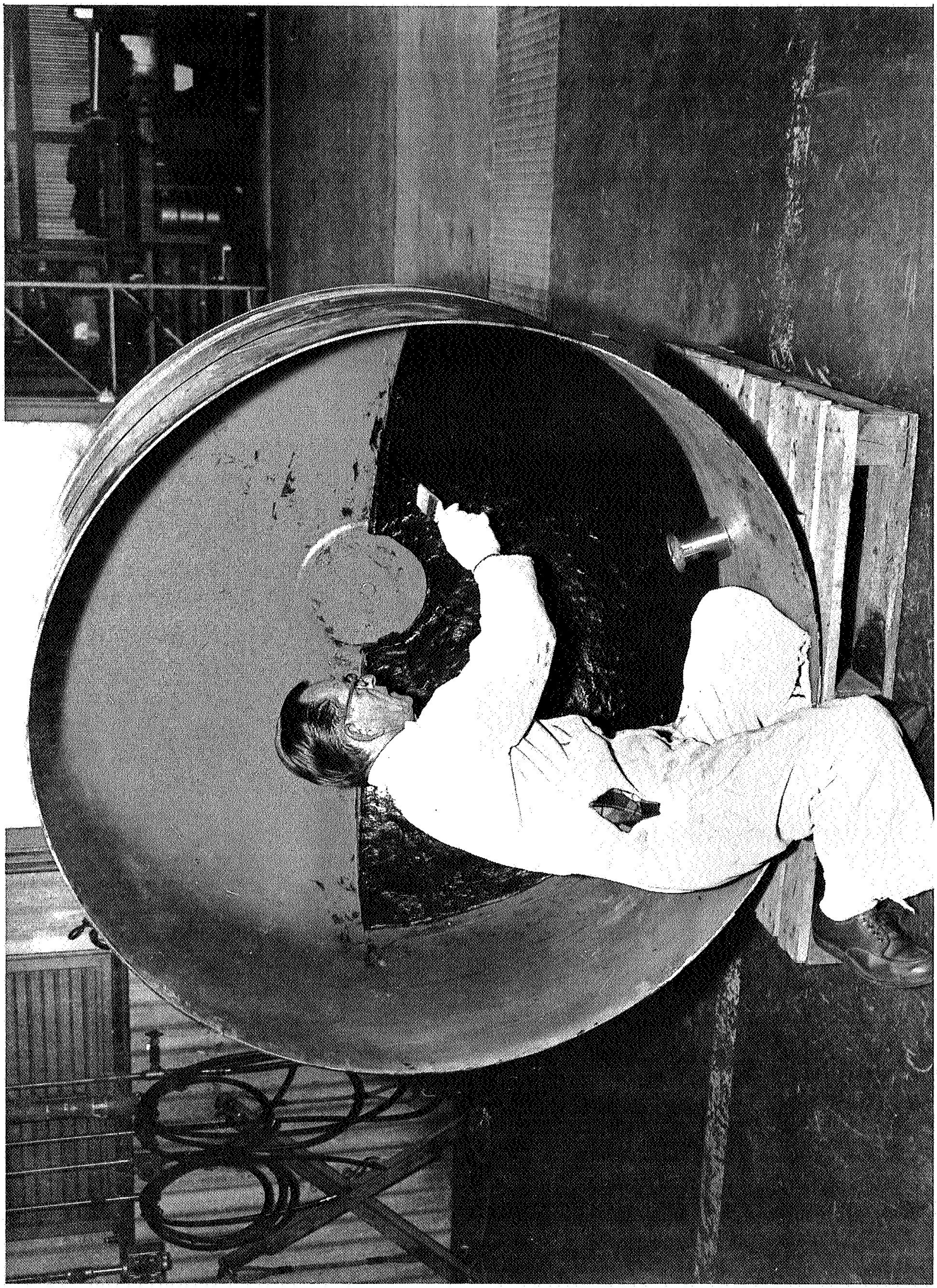
IBT-100 Dome Insulation/IBT-106 Propellant Boot Insulation Demonstration

Figure 16



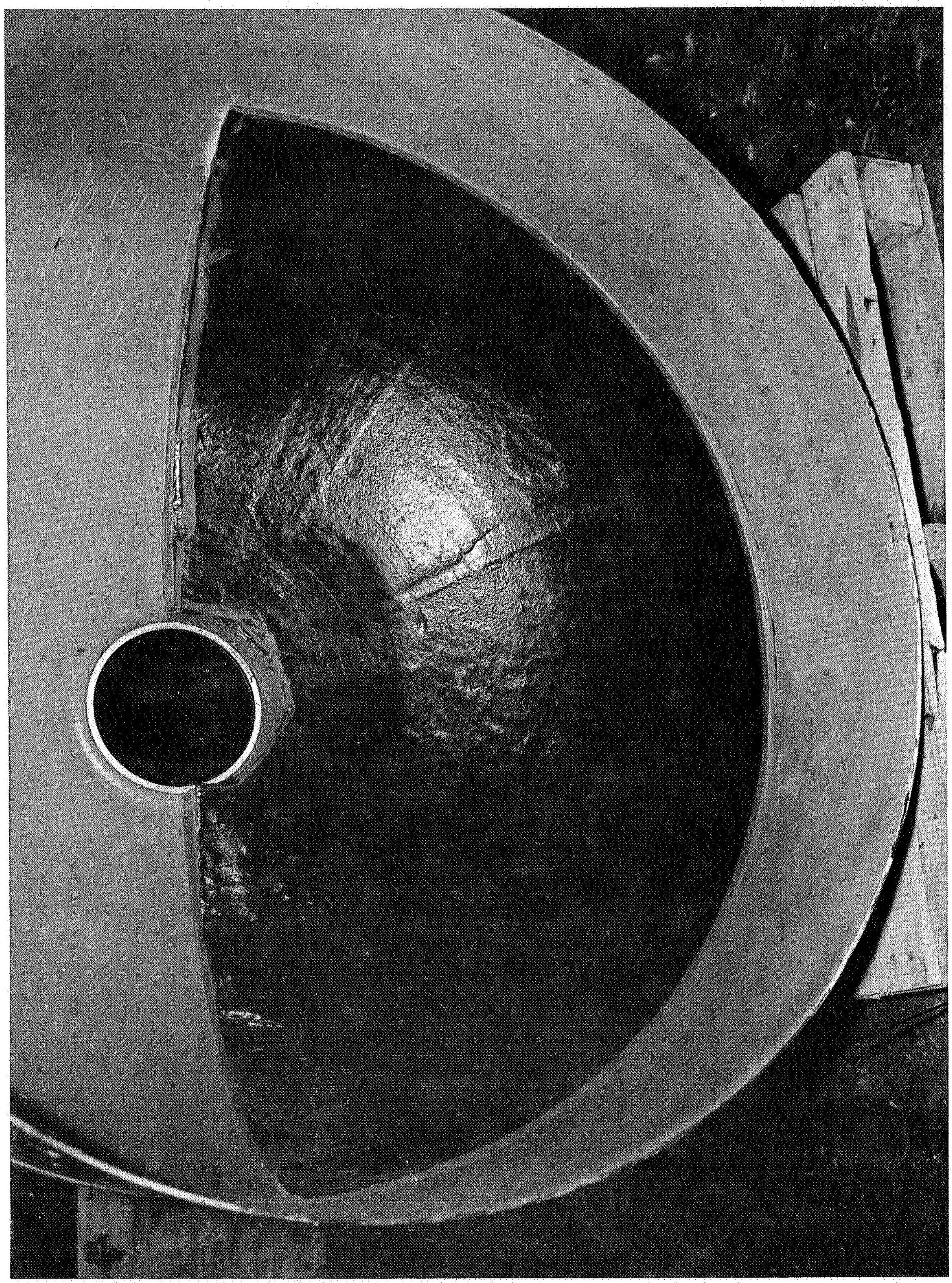
Completed IBT-100 Forward Dome Insulation

Figure 17



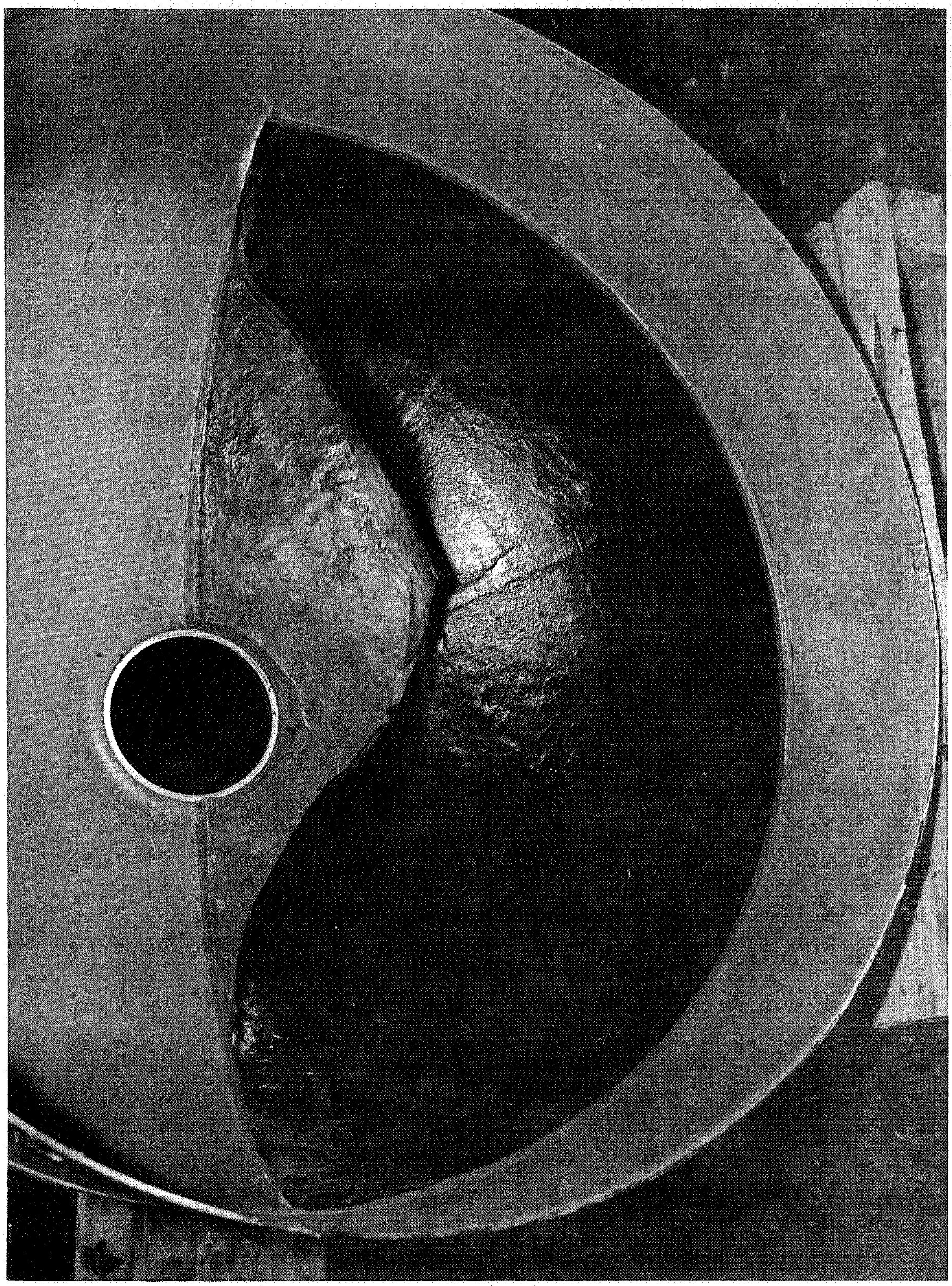
Application of Release to Forward Dome Insulation Surface

Figure 18



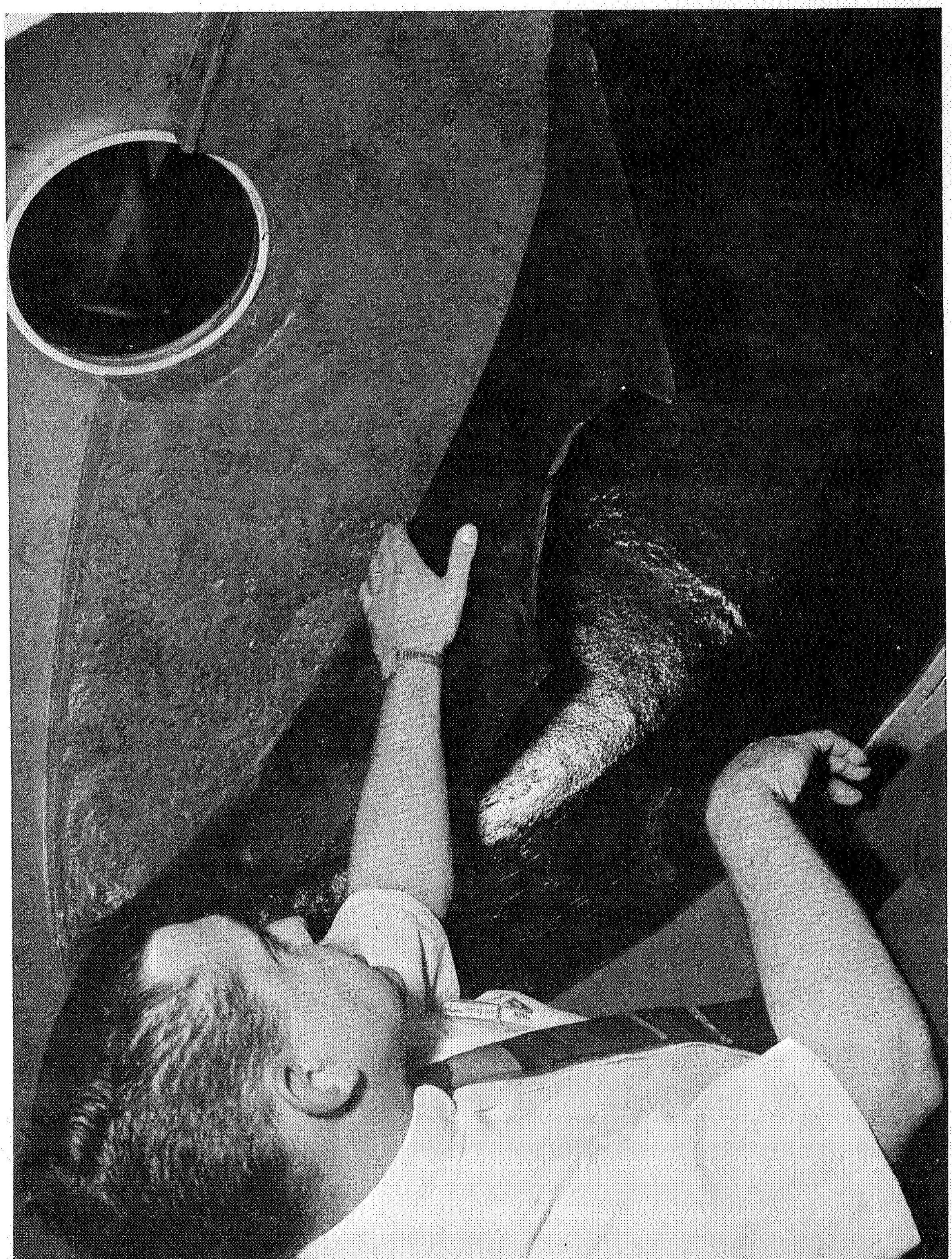
Completed IBT-100 Forward Dome Insulation/IBT-106 Propellant Boot

Figure 19



Completed IBT-100 Forward Dome Insulation/IBT-106 Propellant Boot

Figure 20



Completed IBT-100 Forward Dome Insulation/IBT-106 Propellant Boot

Figure 21

TEST NO. 1	AEROJET GENERAL, NIMBUS, CALIFORNIA
ARTICLE	Aluminum Foil
Size	approx. 14" x 18"
Area Coated	full coverage
No Coats	one - multiple passes
Samples	one
MATERIAL	Aerojet #109 Batch #2
Manufacturer	Aerojet Company
Address	Nimbus, California
Reducer	MEK
Reduction	30%
Viscosity	Unknown
Temperature	140° F. (Paint heater 160° water temp.)
Condition	Sprayed in cross draft w/w booth, ambient temp. 70° F.
Samples	one
DRYING	
Air	12 hrs. @ 65° F.
Bake	3 hrs. @ 140° F.
Cool	
COMPRESSOR	
C.M.F.	
H.P.	
GUN	JGA-502
Air Cap	777
C.F.M./Cap	26.7 @ 80 P.S.I. and 17.6 @ 50 P.S.I.
Fluid Tip	.070
Number Guns	one
HOSE	
Main Air	Std.
Atomization	fair to good
Cylinder	
Fluid	H-1973 3/8" I.D. - tank to heater - heated hose to gun
MATERIAL FEED	Pressure feed tank
Agitation	None required after original mixing with air agitator
REGULATION	
Atomization	P-HLG-501 air transformer
Fluid	Pressure tank
ADJUSTMENTS	
Atom. Press.	80 P.S.I. and 50 P.S.I.
Fluid Press.	100 P.S.I.
Spreader Adj.	Partially closed to give 8" pattern @ 8"
Fluid Adj.	open
Gun Dist.	8" from target
Gun Centers	
Spindle Centers	
Spindle R.P.M.	Note - upper half of sheet sprayed at 80 P.S.I.
Conveyor Width	causing ripples in coating from high air blasting at
Conveyor Speed	distance of 8". Lower portion of sheet sprayed at
Sprocket Centers	50 P.S.I. at 10" distance.
Cycles per Min.	
Production	

DeVilbiss Co. Data Sheet for IBS-109 Sprayable Test Panel No. 1

Figure 22

TEST NO. 2	Aerojet General, Nimbus, California
ARTICLE	Aluminum Foil
Size	approx. 14" x 18"
Area Coated	full coverage
No Coats	one
Samples	one
MATERIAL	Aerojet #109 Batch #2
Manufacturer	Aerojet Company
Address	Nimbus, Calif.
Reducer	MEK
Reduction	30%
Viscosity	unknown
Temperature	160° F. (paint heater 180° water temp)
Condition	Sprayed in cross draft w/w booth, ambient temp. 70° F.
Samples	one
DRYING	
Air	12 hrs. @ 65° F.
Bake	3 hrs. @ 140° F.
Cool	
COMPRESSOR	
C.M.F.	
H.P.	
GUN	JGA-502
Air Cap	777
C.F.M./Cap	17.6 @ 50 P.S.I.
Fluid Tip	.070
Number Guns	one
HOSE	
Main Air	standard
Atomization	fair to good
Cylinder	
Fluid	H-1973 3/8" I.D. - tank to heater - heated hose to gun
MATERIAL FEED	Pressure feed tank
Agitation	none required after original mixing with air agitator
REGULATION	
Atomization	P-HLG-501 air transformer
Fluid	Pressure tank
ADJUSTMENTS	
Atom. Press.	50 P.S.I.
Fluid Press.	100 P.S.I.
Spreader Adj.	partially closed for 12" pattern
Fluid Adj.	open
Gun Dist.	12" from target
Gun Centers	
Spindle Centers	Results improved due to temperature, lower
Spindle R.P.M.	atomizing air pressure and gun distance.
Conveyor Width	
Conveyor Speed	
Sprocket Centers	
Cycles per Min.	
Production	

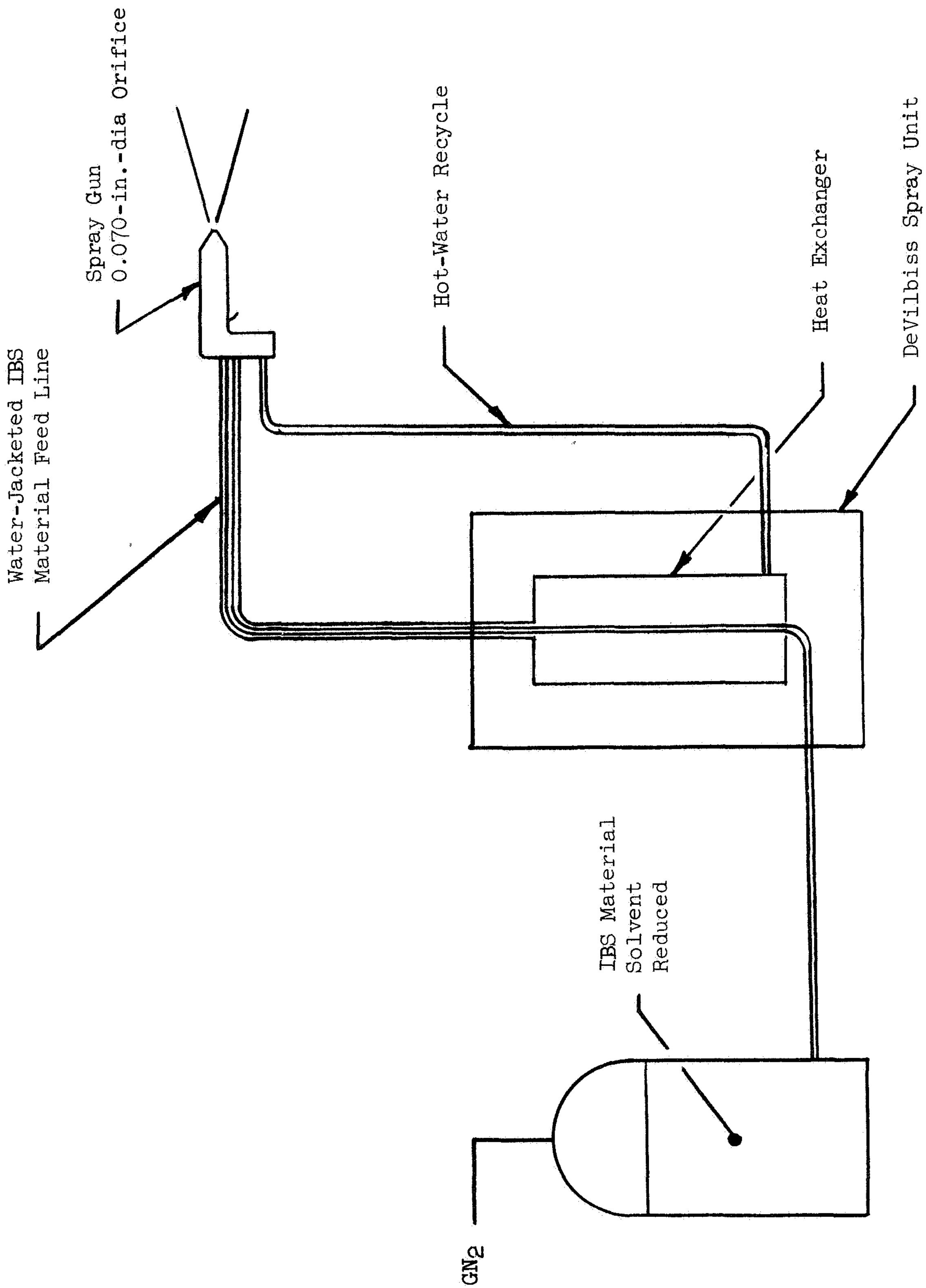
DeVilbiss Co. Data Sheet for IBS-109 Sprayable Test Panel No. 2

Figure 23

TEST NO. 3 & 4	AEROJET GENERAL, NIMBUS, CALIFORNIA
ARTICLE	Aluminum Foil
Size	approx. 12" x 12"
Area Coated	full coverage
No Coats	one - multiple passes
Samples	one
MATERIAL	109 - Batch #1
Manufacturer	Aerojet General
Address	Nimbus, California
Reducer	Trichloroethylene
Reduction	30%
Viscosity	unknown
Temperature	160° F. (paint heater used - water temp. 180° F.)
Condition	cross - draft booth
Samples	one
DRYING	
Air	24 hrs. @ ambient (65° F.) 140°
Bake	2 hrs. @ 140° F.
Cool	
COMPRESSOR	
C.M.F.	
H.P.	
GUN	JGA-502
Air Cap	777
C.F.M./Cap	17.6 @ 50 P.S.I.
Fluid Tip	.070
Number Guns	one
HOSE	
Main Air	standard
Atomization	5/16" I.D. air
Cylinder	
Fluid	H-1973 3/8" I.D. - tank to heater - heated hose to gun
MATERIAL FEED	Pressure feed tank
Agitation	none required after original mixing with air agitator
REGULATION	
Atomization	P-HLG-501 air transformer
Fluid	Pressure tank
ADJUSTMENTS	
Atom. Press.	50 P.S.I.
Fluid Press.	100 P.S.I.
Spreader Adj.	partially closed for 12" pattern
Fluid Adj.	
Gun Dist.	18" from target
Gun Centers	
Spindle Centers	
Spindle R.P.M.	
Conveyor Width	Test #3 was one pass in 10 seconds
Conveyor Speed	
Sprocket Centers	
Cycles per Min.	
Production	

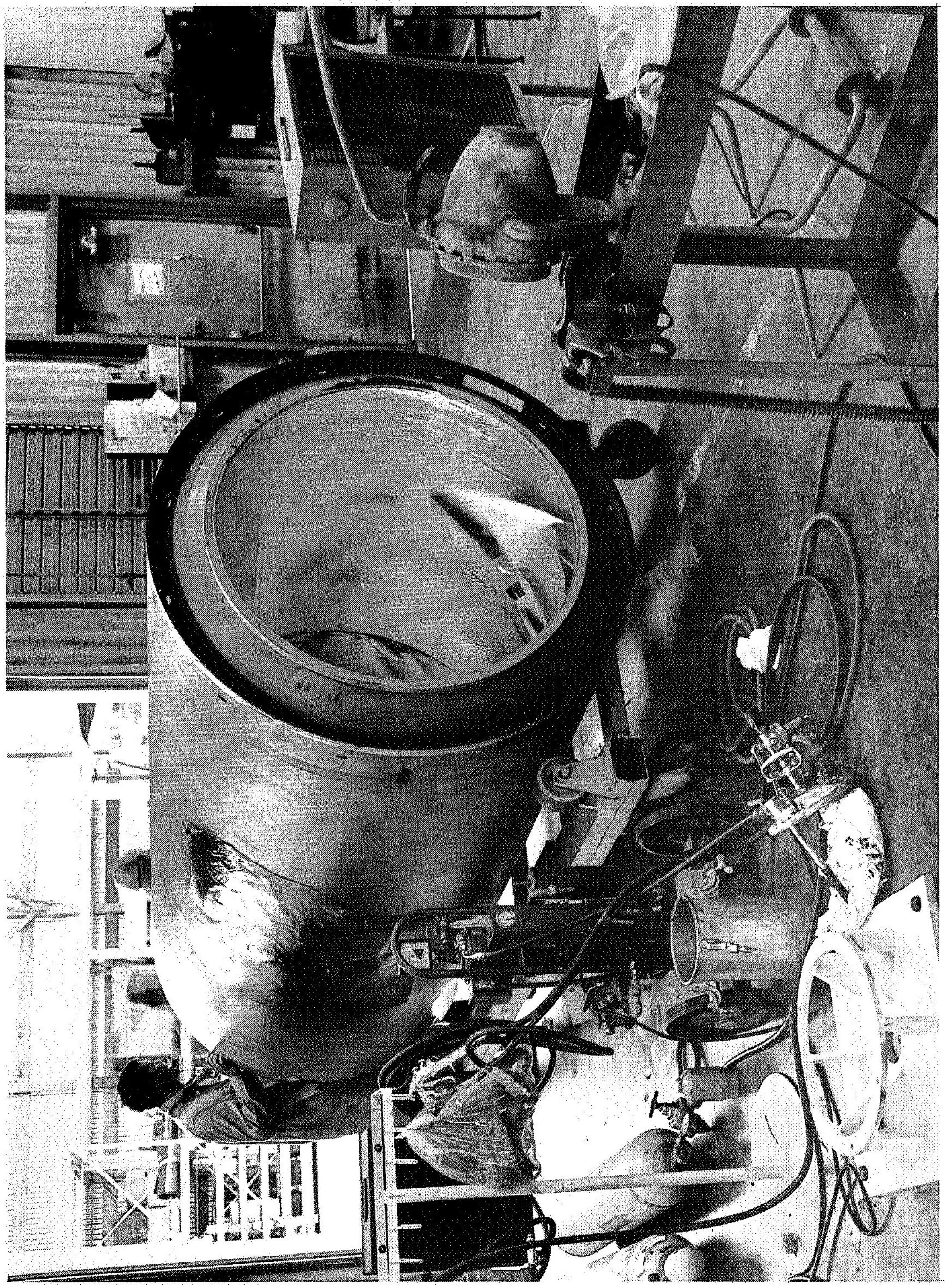
DeVilbiss Co. Data Sheet for IBS-109 Sprayable Test PanelsNos. 3 & 4

Figure 24



Schematic Diagram of Insulation Spray Setup

Figure 25



Sprayable Insulation Demonstration Setup

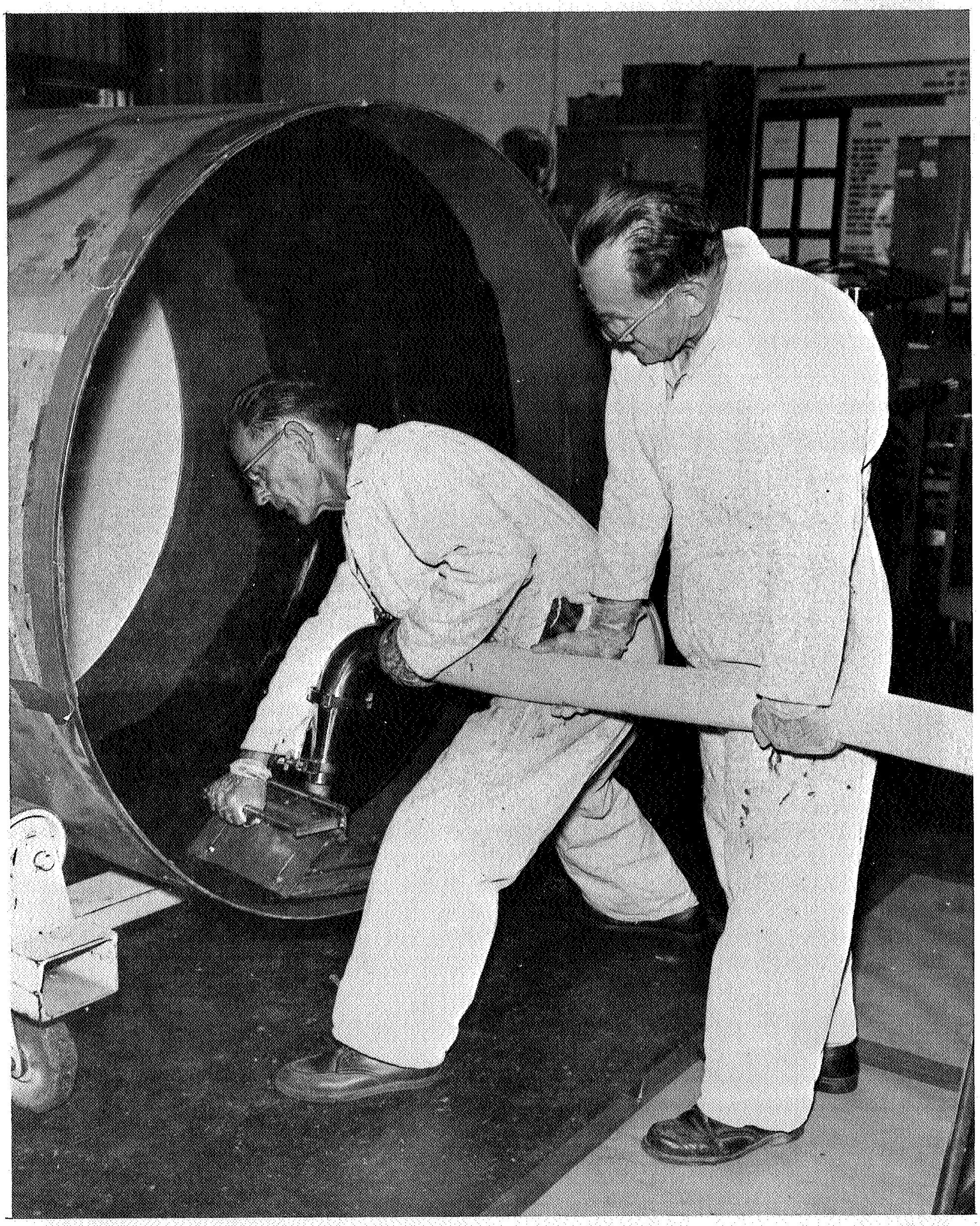
Figure 26

Spray Application of ITS-109

Figure 27

Spray Application of IBS-107

Figure 28

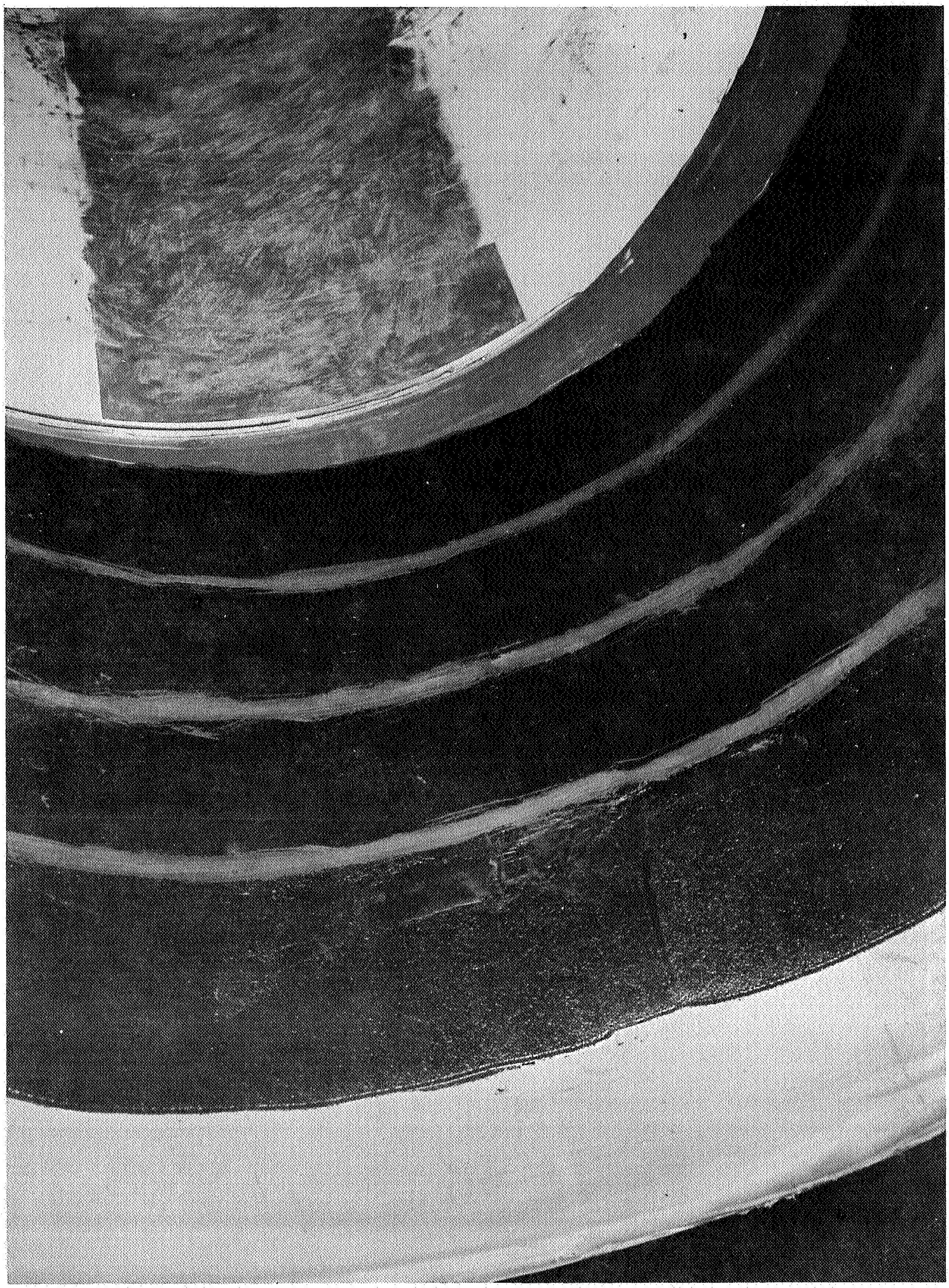


Installation of IBT-106 Sidewall Insulation

Figure 29

Installation of IBT-106 Sidewall Insulation

Figure 30



Completed IBT-106 Sidewall Insulation Demonstration

Figure 31

FWD DOME

V-45	precured components, secondarily bonded; V-61 joints
IBT-100	troweled
IBT-106-1	troweled
IBC-111	cast
40SD-80	cast
TI-H704B	special tamping process

SIDEWALL

V-45	precured strips, secondarily bonded; lapped joints
IBT-106-2	troweled
IBS-107	sprayed
IBS-109	sprayed
TI-H704B	special tamping process

AFT DOME & NOZZLE

V-44	precured components, secondarily bonded; V-61 joints
USR-3800	precured components, secondarily bonded; V-61 joints
IBT-100	troweled
IBT-106-1	troweled
IBC-111	cast
40SD-80	cast
TI-H704B	special tamping process

BOOTS

V-45	precured components, secondarily bonded; Germax V-45 seams
IBT-106-2	troweled
IBS-107	sprayed
IBS-109	sprayed
TI-H704B	special tamping process

Candidate Insulation Systems

Figure 32

INSTALLATION SPAN TIME, 8 HR SHIFTS

	Actual 260SL-1	Actual 260SL-2	Actual 260SL-3	Estimated 260FL
Fwd/Aft Domes				
V-44	21	18	N/A	18
IBT-100 Trowelable	-	-	-	14
IBC-111 Castable	-	-	-	19
Propellant Boots				
V-45	24	18	30	24
IBT-106 Trowelable	-	-	-	19
Sidewall				
V-44	18*	30**	9***	20***
IBT-106 Trowelable	-	-	-	16

For 260FL Motor:

V-44/V-45 System - 62 Shifts or 20.7 Days

IBT-100/IBT-106 System - 49 Shifts or 16.3 Days

---

* 2 plies - 0.10 thick
** 3 plies - 0.10 thick
*** 1 ply - 0.20 thick/V-61 Seams

Comparison of Estimated Insulation Installation
Span Times for 260-FL Motors

Figure 33

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